Worthing Borough Heatmapping & Masterplanning Report

Worthing Borough Council

Project Number: 60630054

August 2020

Quality information

Prepared by	Checked by	Verified by
Sam Shuttleworth Energy Engineer	Matthew Turner Regional Director	Matthew Turner Regional Director

Revision History

Revision	Revision date	Details	Name	Position
DRAFT	02/07/20	Draft	Freddie Harcourt	Energy Engineer
01	03/08/20	First Issue	Sam Shuttleworth	Energy Engineer
02	10/08/20	WBC Comments Incorporated	Sam Shuttleworth	Energy Engineer
03	10/08/20	BEIS Comments Incorporated	Sam Shuttleworth	Energy Engineer

Prepared for:

Worthing Borough Council

AECOM Limited
Aldgate Tower
2 Leman Street
London E1 8FA
United Kingdom
aecom.com

© 2020 AECOM Limited. All Rights Reserved.

This document has been prepared by AECOM Limited (“AECOM”) for sole use of our client (the “Client”) in accordance with generally accepted consultancy principles, the budget for fees and the terms of reference agreed between AECOM and the Client. Any information provided by third parties and referred to herein has not been checked or verified by AECOM, unless otherwise expressly stated in the document. No third party may rely upon this document without the prior and express written agreement of AECOM.

Table of Contents

Executive Summary 4
1. Introduction 5
  1.1 Objectives 5
  1.2 Methodology 5
2. Energy Demand Mapping 6
  2.1 Heat Demand Map with Identified Heating Clusters 6
  2.2 Cooling Demand 7
  2.3 Potential Funding Routes for Network Development 8
  2.4 Appraisal of Energy Demand Clusters 8
3. Suitable Generational Technologies 9
  3.1 Geographical Suitability 9
  3.2 Qualitative Assessment 10
4. Optioneering Analysis 11
5. Developed Solutions 12
  5.1 Cluster A – Worthing Town Centre 12
  5.2 Cluster B: Worthing Leisure Centre 14
  5.3 Cluster C: Northbrook College Campus 16
  5.4 Cluster D: Salvington Hill 18
  5.5 Cluster E: Centenary House 20
  5.6 Cluster F:Northbrook Central Campus 22
6. Conclusions 24
  6.1 Technical 24
  6.2 Environmental 24
  6.3 Economic 24
  6.4 Funding Routes 25
  6.5 Planning policy 25
7. Recommendations & Next Steps 26
  7.1 Summary 26
  7.2 Next Steps & Key Risk items for Development 26

Appendix A – Illustrative Overview of Heat Networks 27
Appendix B – Energy Load Information 28
Appendix C – Generation Plant Appraisal 29
Appendix D – Key Modelling Assumptions 33
Appendix E – Full Modelling Results 35

Executive Summary

The Adur and Worthing Council Carbon Neutral Plan, published December 2019, identified that the key actions and interventions required for the Councils to meet their net zero carbon emissions target. One of the key measures was the need to transition all existing heating systems, most of which use gas boilers, to lower carbon systems, with District Energy Networks (DEN) recognised as a possible part of the strategy to achieve this goal.

Given the anticipated continued decarbonisation of the UKs electrical grid, the utilisation of electrically fuelled heat pump systems can facilitate this transition. This can be achieved in one of two ways:

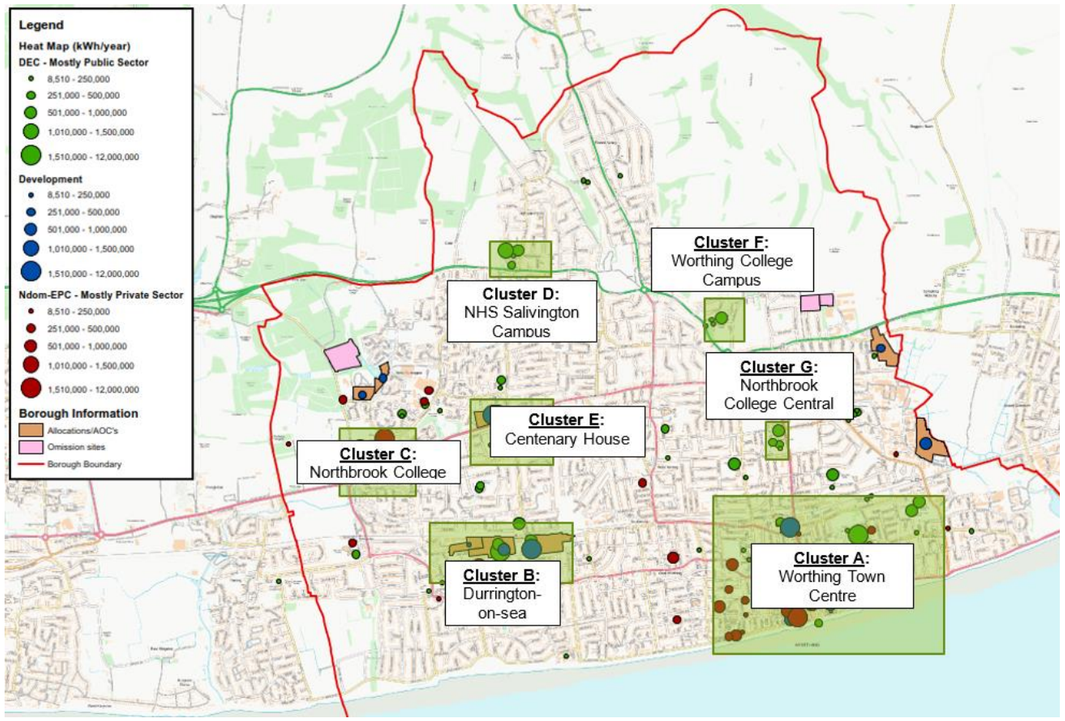
- Via replacement of gas boilers within each building with heat pumps, with air source systems typically being the most deliverable solution; or
- Via the creation of a heat-pump led district heating network.

The aim of this heat mapping and masterplanning study is to identify:

- Opportunities to expand the proposed Civic Quarter network throughout Worthing town centre to deliver increased carbon savings and improved network economics; and
- Additional opportunities where the council can use its direct or indirect influence to trigger the development of other low carbon heat networks in the Borough.

Within the Worthing area, there were found to be:

- Six suitable building clusters to implement district heating schemes, based around both dense existing urban environments and proposed developments of significant size; and
- Multiple sources for ambient or waste heat recovery which can facilitate the development of high-efficiency heat pump schemes.



For each identified cluster, a techno-economic optioneering modelling study was undertaken, and preferred solutions identified. Based on analysis of the modelling results, it can be concluded that there are economic and environmental benefits to the creation of a network in all six locations as they would:

- Offer a lower cost route to heating system decarbonisation when compared against building-level heat pump installations;
- All the developed solutions have been designed to reduce the resultant CO_2 emissions arising from the provision of heating in by:
    - Up to 90% against the continued use of gas boilers; and
    - Up to 5% against the alternative decarbonisation scenario in which all buildings convert their current heating systems to air source heat pumps.

The identified solutions could be partially funded utilising two potential UK-treasury financed grant funding schemes:

1. Heat Networks Investment Programme: The larger identified networks meet the minimum heat generation criteria for this capital funding scheme; and / or
2. Renewable Heat Incentive: The smaller schemes, which could be delivered before March 2022, could access this operational funding scheme.

It is recommended that solutions for all clusters are further developed by:

- Approaching all identified key loads to ascertain their current energy demands and carbon reduction agendas, and their likely appetite to connect in either the short or long terms;
- Development of the technical solution to de-risk the solution, primarily relating to the thermal generation and distribution systems;
- Undertaking further detailed techno-economic feasibility analysis; and
- Identifying preferred procurement and ownership structures.

1. Introduction

On July 9th, 2019, the Joint Strategic Committee of Adur & Worthing Councils (A&WC) declared a Climate Emergency and committed to working towards carbon neutral operation by 2030. The A&WC Carbon Neutral Plan, published December 2019, identified that the key actions and intervention measures required for the Councils to meet their net zero carbon emissions target. One of the key measures was the need to transition all existing heating systems, most of which use gas boilers, to lower carbon systems, with District Energy Networks (DEN) recognised as a possible part of the strategy to achieve this goal.

DENs are perceived by the UK Government as a key tool in the country's decarbonisation strategy. Energy, in the form of heated or cooled water, is generated at a centralised location (termed the Energy Centre, EC) and distributed through a pipe network to end users. This presents opportunities which are not available to individual energy consumers, such as the utilisation of waste heat (e.g. from industry) or ambient heat sources (e.g. solar energy captured by bodies of water, such as the sea). Refer to Appendix A for a detailed description of DENs.

AECOM has been commissioned by Worthing Borough Council (WBC) to undertake a Heat Mapping and Masterplanning study looking at the potential for DENs across the Borough of Worthing. This report forms the key deliverable for the study which has been completed in line with the Heat Network Delivery Unit (HNDU) guidelines. The red-line boundary for this study is taken from the Draft Worthing Local Plan, as shown in Figure 1-1.

This project is being delivered in parallel to a detailed Techno-Economic Feasibility assessment looking at the viability for a scheme in at specific area of Worthing town centre - the Civic Quarter - as this site was specifically identified in the Carbon Neutral Plan as being well suited for the creation of a network. The locality of this site in relation to the Worthing Borough is highlighted in Figure 1-1.

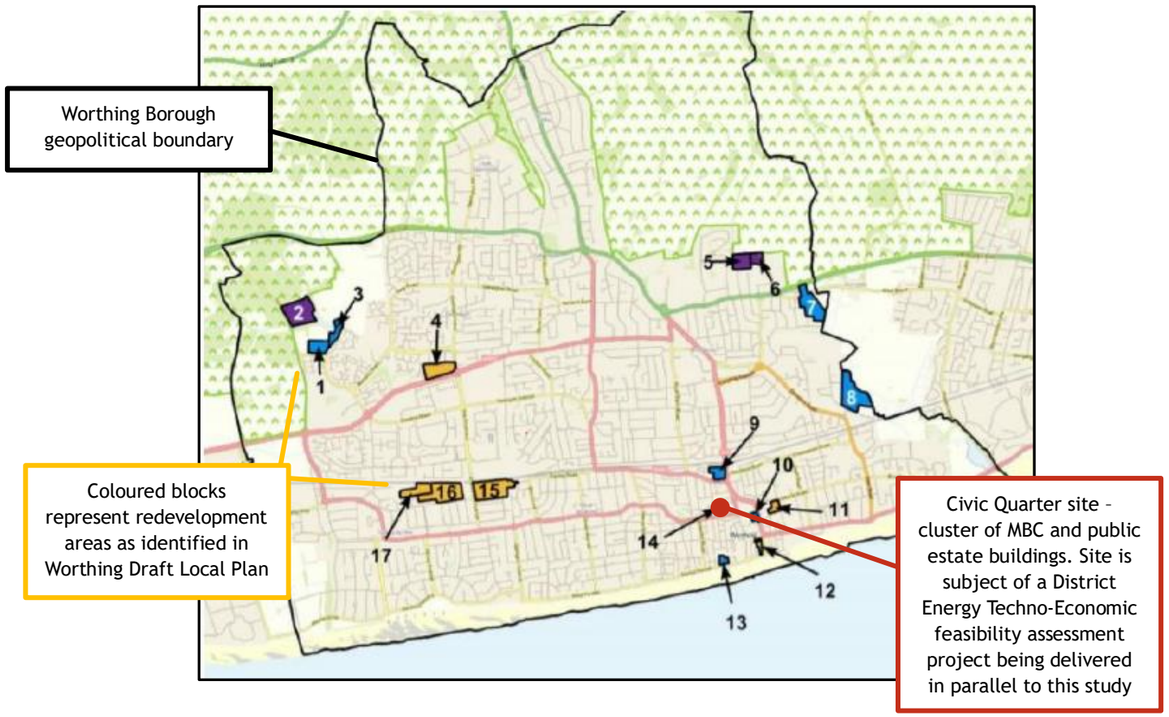


Figure 1-1: Worthing Geopolitical Boundary & sites identified for development. Image taken from Draft Local Plan

1.1 Objectives

The purpose of this study is to identify opportunities and assess the technical and commercial viability of DENs across the study area, covering two aspects:

1. Opportunities to expand the proposed Civic Quarter network throughout Worthing town centre to deliver increased carbon savings and improved network economics; and
2. Additional opportunities where the council can use its direct or indirect influence to trigger the development of other low carbon heat networks in the Borough.

In the correct circumstances, DENs enable the decarbonisation of energy (primarily heat, but can also cover cooling and / or power requirements) at a lower cost compared to building level solutions. The viability of these schemes depends on their being both:

- significant enough energy demands within an area to justify the capital expense of installing the distribution networks; and
- the availability of waste or ambient energy sources that can be harnessed to generate the required low or zero carbon energy.

Where this study identifies potentially viable schemes (in environmental and economic terns), it has been recommended that they be considered to proceed to the next HNDU stage of works; Techno-Economic Feasibility.

1.2 Methodology

The methodology developed to undertake this study is summarised below.

1. **Data Collection:** Energy load data was collected for all existing commercial sites, existing multi-tenancy residential blocks and planned developments within the study area. Of the existing buildings identified, only those which are estimated to be compatible with a District Heat network proceed to the next stage of the assessment were taken forward to the assessment stage. For this reason, many smaller and industrial buildings are not mapped in this report. For more information see Appendix B.
2. **Energy Demand Mapping:** Using the energy demand analysis, energy maps were produced which illustrate the size and location of the heating and cooling clusters within Worthing. Each cluster was then qualitatively appraised with the client team, and those which were considered to represent a realistic opportunity were taken forward for further analysis.
3. **Low Carbon Heat Opportunities:** A desktop survey has been undertaken to identify opportunities to supply low carbon heat with a focus on quantifying sources close to areas of high demand. A high-level review of the available technologies was carried out by assessing their suitability against deliverability, environmental, financial and technical criteria.
4. **Techno-economic Modelling of Preferred Solutions:** Network masterplans were developed for each cluster, with multiple scenarios developed where more than one technical solution is possible. A high-level quantitative Techno-Economic analysis was undertaken to ascertain the level of environmental and economic performance of each of the network solutions identified.
5. **Recommendations** as to which areas represent are suitable for further investigation were made.

2. Energy Demand Mapping

2.1 Heat Demand Map with Identified Heating Clusters

The below map details the heating loads identified within the red line boundary and highlights the locations where there are clusters of demand that could represent opportunities for district heating systems.

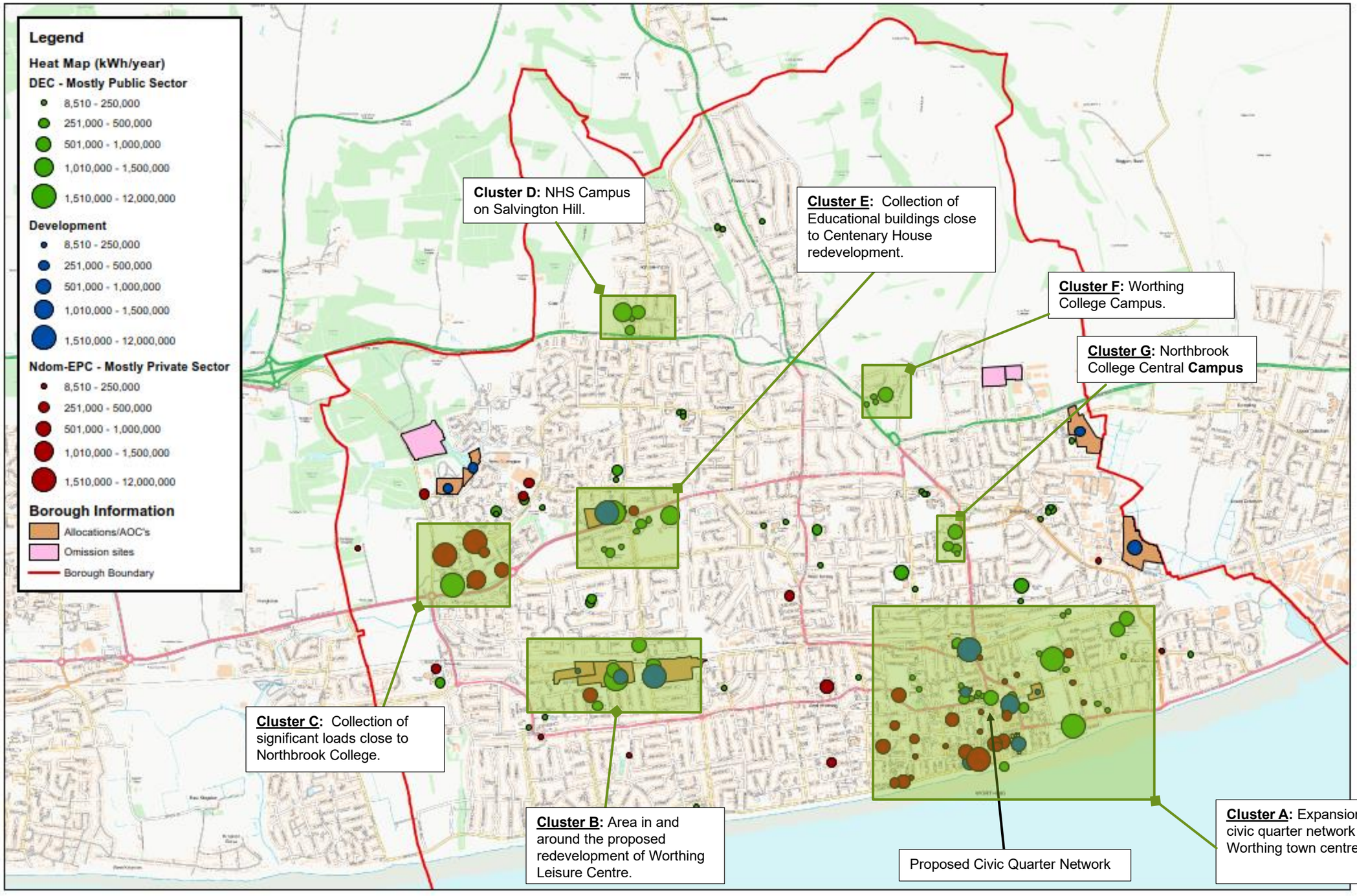

Legend
Heat Map (kWh/year)
DEC - Mostly Public Sector
8,510 - 250,000
251,000 - 500,000
501,000 - 1,000,000
1,010,000 - 1,500,000
1,510,000 - 12,000,000
Development
8,510 - 250,000
251,000 - 500,000
501,000 - 1,000,000
1,010,000 - 1,500,000
1,510,000 - 12,000,000
Ndom-EPC - Mostly Private Sector
8,510 - 250,000
251,000 - 500,000
501,000 - 1,000,000
1,010,000 - 1,500,000
1,510,000 - 12,000,000
Borough Information
Allocations/AOC's
Omission sites
Borough Boundary
Cluster D: NHS Campus on Salvington Hill.
Cluster E: Collection of Educational buildings close to Centenary House redevelopment.
Cluster F: Worthing College Campus.
Cluster G: Northbrook College Central Campus
Cluster C: Collection of significant loads close to Northbrook College.
Cluster B: Area in and around the proposed redevelopment of Worthing Leisure Centre.
Proposed Civic Quarter Network
Cluster A: Expansion of civic quarter network around Worthing town centre.

Figure 2-1: Heat Load Map for the Borough of Worthing

2.2 Cooling Demand

The below map details the cooling loads identified within the red line boundary, with no clusters of sufficient enough cooling demand to warrant further investigation into a district cooling network.

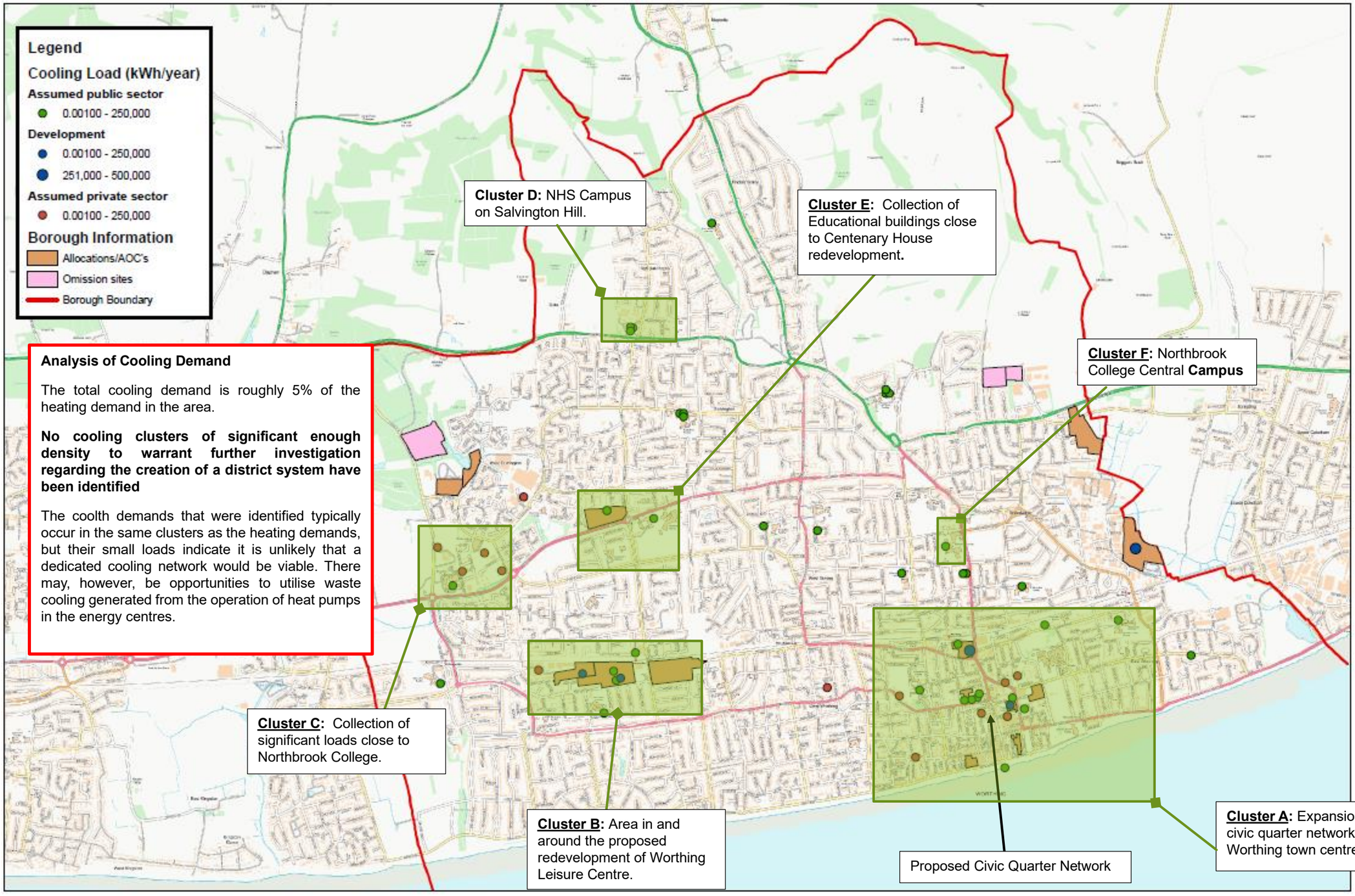

Legend
Cooling Load (kWh/year)
Assumed public sector
0.00100 - 250,000
Development
0.00100 - 250,000
251,000 - 500,000
Assumed private sector
0.00100 - 250,000
Borough Information
Allocations/AOC's
Omission sites
Borough Boundary
Analysis of Cooling Demand
The total cooling demand is roughly 5% of the heating demand in the area.
No cooling clusters of significant enough density to warrant further investigation regarding the creation of a district system have been identified
The coolth demands that were identified typically occur in the same clusters as the heating demands, but their small loads indicate it is unlikely that a dedicated cooling network would be viable. There may, however, be opportunities to utilise waste cooling generated from the operation of heat pumps in the energy centres.
Cluster D: NHS Campus on Salvington Hill.
Cluster E: Collection of Educational buildings close to Centenary House redevelopment.
Cluster F: Northbrook College Central Campus
Cluster C: Collection of significant loads close to Northbrook College.
Cluster B: Area in and around the proposed redevelopment of Worthing Leisure Centre.
Proposed Civic Quarter Network
Cluster A: Expansion of civic quarter network around Worthing town centre.

Figure 2-2: Cooling Load Map for the Borough of Worthing

2.3 Potential Funding Routes for Network Development

There are two potential UK government funding routes that shall be considered when determining the viability of the different network clusters.

Scheme	Summary	Key barriers to obtain funding
Heat Networks Investment Programme (HNIP)	Source of grant funding or low-interest loans to provide the gap funding typically required to boost schemes with low levels of economic returns to an attractive enough level to attract the additional investment required to fund the scheme.	Scheme must generate over 2MWh of heat per annum
Renewable Heat Incentive (RHI)	Contributes an additional source of revenue source based upon the amount of low carbon heat delivered per annum, required to boost schemes with low levels of economic returns based on their adoption of low-carbon heating technologies (e.g. heat pumps).	Scheme must be of a small scale or with only one heat customer so that the plant can be operational prior to the funding cut-off date of March 2022.

Table 2-1: Potential UK government funding routes available to support the delivery of low carbon district heating networks

2.4 Appraisal of Energy Demand Clusters

The energy mapping exercise has identified six geographical heat demand clusters, which are presented in Table 2-2 below. No suitable cooling demand clusters were identified for further consideration.

Cluster	Key Existing Buildings & Future Developments	Total Identified Heating Load GWh/year	Meets heat demand criteria for HNIP funding	Could be delivered in time to achieve RHI funding	Cluster Taken Forward for Further Analysis
A	Civic Quarter Network, Worthing Hospital, Splashpoint Leisure Centre & Multiple Development Sites	Current: 29.9 Future: 35.6	✓	✗	✓
B	Worthing Leisure Centre, HMRC Office and Martlett Way Areas of Change.	Current: 5.1 Future: 4.7	✓	✗	✓
C	Northbrook College, St Barnabas Hospice & Haviland House Care home.	7.5	✓	✗	✓
D	Sussex Partnership Foundation Trust HQ, The Burrows Hospital, misc. NHS Buildings	2.4	✓	✓	✓
E	Centenary House Development, Durrington High School, Oak Grove College	Current: 4.9 Future: 5.1	✓	✗	✓
F	Northbrook College Central Campus & Bohunt School	1.3	✗	✓	✓

Table 2-2: Summary of the clusters identified through heat mapping.

Clusters A, B, C, D and E are considered to be deliverable due to the:

- presence of local authority sites in each cluster, who could champion the uptake of a heat network in the area; and
- containing sufficient heat demand to meet the basic eligibility requirement to be able to apply for gap funding through the Heat Networks Investment Project (HNIP funding) funding programme.

It has been assumed that the following clusters could seek RHI funding as they are considered to be deliverable in time to meet the March 2022 deadline:

- Cluster D is as it is comprised entirely of NHS building stock, thereby significantly reducing the time required to take a scheme to market; and
- Cluster F (which is too small to be considered to be eligible for HNIP), as it is a small scheme which delivers heat to only two stakeholders, which could significantly reduce the time required to take a scheme to market if either one were to undertake procurement of the scheme.

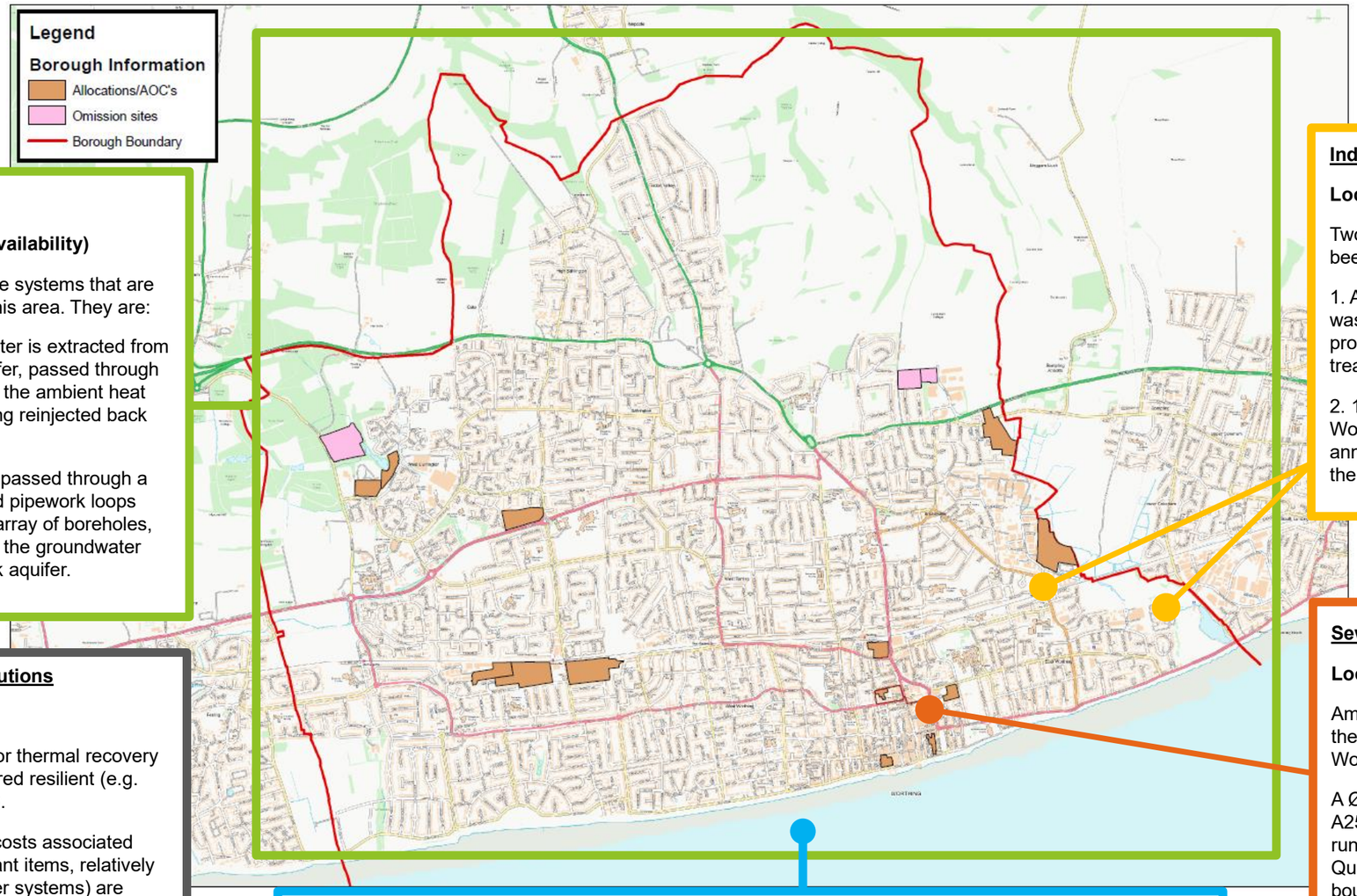
The larger number of stakeholders involved in all the other clusters would result in the time required to undertake any procurement exercise for the schemes to cause the heat on date to be after the March 2022 cut-off date for RHI.

Following a qualitative review, undertaken by AECOM and agreed with WBC, it is agreed that all clusters shall be taken forward into the masterplanning and techno-economic modelling stage of this study.

3. Suitable Generational Technologies

3.1 Geographical Suitability

The potential energy generation technologies identified across the study area are presented in Figure 3-1 below, including both Low to Zero (LZC) carbon solutions and established gas-combustion technologies. Many of the solutions are based upon the recovery of either ambient or waste energy from sources which are geographically sensitive and can therefore only be applied to certain demand clusters.



Ground Source Heat Pumps

Location: Any (subject to space availability)

There are two types of ground source systems that are deemed geographically suitable to this area. They are:

1. Open loop; where groundwater is extracted from the subterranean chalk aquifer, passed through a heat exchanger to capture the ambient heat contained within, before being reinjected back into the aquifer.
2. Closed loop; where water is passed through a series of hydraulically sealed pipework loops which pass through a large array of boreholes, capturing ambient heat from the groundwater held within the soil and chalk aquifer.

Resilient & peak heating plant solutions

Location: Any

LZC systems subject to curtailment or thermal recovery from a third party cannot be considered resilient (e.g. OL-GSHP and industrial waste heat).

Furthermore, given the high capital costs associated with installing the majority of LZC plant items, relatively cheap peaking plant items (e.g. boiler systems) are typically used to meet the peak requirements of the networks during periods of high demand.

For this reason, the majority of the LZC led DENs solutions analysed later in this report will utilise gas boilers to provide resilience and peaking capacity.

Marine Source Heat Pump (MSHP).

Location: Coastal areas

Ambient heat is extracted from sea water. To abstract the required quantity of sea water, an open loop system is typically used, with a pipeline required to abstract the sea water prior to it passing through a heat exchanger (tailored to operate with saline water) prior to being rejected back out to sea.

Industrial Waste Heat Opportunities

Location: East Worthing

Two industrial waste heat opportunities have been identified:

1. A Southern Water treatment plant, where waste heat from the effluent treatment processes can be captured from the outflow of treated water; and

2. 132 KV transformer, located near East Worthing train station, where circa 1GWh per annum of waste heat can be recovered from the cooling systems.

Sewer Source Heat Pump

Location: Worthing Town Centre

Ambient heat is extracted from the flow within the main sewer line travelling through Worthing.

A Ø1.5m sewer line is located beneath the A259 / High Street in Worthing town centre, running approximately 200m east of the Civic Quarter site, and adjacent to the eastern boundary of the Union Place development.

Based on preliminary investigations based upon modelled flow rates received from Southern Water, it is anticipated that a SSHP plant installation of up to c.3MW could be installed on this sewer line.

Figure 3-1: Energy recovery and generation opportunities

3.2 Qualitative Assessment

Table 3-1 below presents the results from the qualitative assessment of the different viable technological solutions identified in the Borough, and the applicability of each to the different energy clusters. This analysis has been based upon criterion such as geographical availability, technology maturity and cost, anticipated risk profile and alignment WBC's environmental goals. For full details on how the scoring and ranking was derived, refer to Appendix C.

The outputs from the assessment shall be used to identify the technology options to be taken forward into the Techno-Economic assessments for the different clusters.

		Suitability Score			Suitability of Technology to Each Energy Cluster		
Rank	**Energy Generation Plant / Recovery Source**	**Short Term, 0-15 years**	**Long Term, 15+ years**	**Commentary**	**Cluster A: Worthing Town Centre**	**Clusters B, C, D, E and F:**	**Taken forward for further analysis**
1	Closed-Loop Ground Source Heat Pump (CL-GSHP)	83% / 87%		Large potential resource with several successful example projects in the UK	✓	✓	✓
2	Marine Source Heat Pump (MSHP)	82% / 87%		Large potential resource but poses significant technical challenge associated with water abstraction	✓	✗	✓
3	Open-Loop Ground Source Heat Pump (OL-GSHP)	82% / 86%		Large potential resource with several successful example projects in the UK	✓	✓	✓
4	Air Source Heat Pump (ASHP)	80% / 85%		Lowest efficiency heat pump system but viable at most locations with available outdoor space.	✓	✓	✓
5	Sewer Source Heat Pump (SSHP)	78% / 84%		High efficiency but also high capital cost with limited deployment in UK.	✓	✗	✓
6	Southern Water Wastewater Treatment Plant	78% / 83%		Long distance between waste heat and significant heat demands.	✓	✗	✗
7	Gas Boiler	74% / 77%		Low cost plant, with high CO_2 emissions from gas use. Ideal to provide cost effective peaking and backup generational capacity.	✓	✓	✓
8	HV Transformer (East Worthing Rail Station) Heat Recovery	72% / 69%		High technical risk heat source with limited deployment in the UK	✓	✗	✗
9	Gas CHP	69% / 63%		Does not meet WBC's carbon reduction commitments.	✓	✓	✗

Table 3-1: Results from qualitative appraisal of viable energy generation solutions.

Heat Pumps: Electrically fuelled heat pumps represent the best opportunity due to their anticipated carbon performance and availability in the area. Heat pumps abstract heat from a waste (e.g. sewer) or ambient heat source (e.g. air or groundwater) and use electricity to convert it into useful heat which can be used in buildings. The warmer the heat source, the more efficient the heat pump can operate. All the different heat pump solutions were shown to score highly in both the short and long term, with minor scoring differences between the different systems arising from geographic availability, anticipated efficiencies, technology maturity and capital costs. Heat pump viability also improves over time as the electrical grid decarbonises, the technology matures and costs lower.

Waste Heat Sources: The estimated waste energy capacity for either system is unlikely to be sufficient to serve any heat demand given the distance, more than 1.2km, between the source and the nearest significant heat cluster in Worthing Town Centre (Cluster A). Should additional loads be developed in the future between these two points in the future, the potential for collection of the waste heat.

Combustion Plant: The viability of combustion-based plant, both gas and biofuel, was shown to reduce over time. For gas-based systems this is primarily due to incoming planning policy restrictions and anticipated carbon taxation, which will restrict new plant being installed and disincentivise the continued use of existing plant respectively. For biofuel systems, there are concerns over the availability of long-term fuel supply contracts and air quality implications within built up urban areas. Gas boilers are, however, well suited to provide either peaking or backup capacity to any network given their low capital and operational costs.

4. Optioneering Analysis

Each potential solution in each cluster has been modelled within AECOM's Techno-Economic Model (TEM) to provide a comparative assessment of the environmental and economic benefits of each. For full details of the input assumptions, refer to Appendix D.

In order to identify the optimal district heating solution for each cluster, an optioneering study has been conducted in order to identify both the generational plant solution and network scope that result in the lowest whole life cycle for the delivery of heat whilst achieving the maximum levels of CO_2 emissions reductions as possible (in line with WBCs carbon commitments). Table 4-1 below summarises the outcome from this optioneering study. Full results are included in Appendix E.

In order to demonstrate the value for money of the each of the chosen solutions, the resultant Levelised Cost of Heat (LCoH) has been calculated for both the scheme, and following two 'Business as Usual' (BaU) scenarios:

- **BaU #1; Do Nothing:** At present, all the existing buildings identified as potential customers to an energy network generates heating from gas boilers. It is assumed that all new development sites shall be conditioned by planning requirements to generate heating from low carbon sources, with Air Source Heat Pumps being the most technically viable solution for the majority of sites.

- **BaU #2; Alternative Decarbonisation Strategy:** The decarbonisation of heat, which is necessary to meet the UK Governments net-zero target, will require the phasing out of natural gas as a primary heating fuel. There is proposed legislation to prevent gas boilers being installed in new dwellings from 2025 and further policy is anticipated to incentivise the replacement of existing gas boilers with low carbon heating systems, with Air Source Heat Pumps being the most likely solution for individual buildings. For existing buildings operating with heating system temperatures of ~81/70°C flow and return, ASHP efficiency has been modelled at 190%. For new buildings, with heating systems that can be tailored to suit heat pumps, ASHP efficiency has been modelled at 250%.

For all of the considered masterplans analysed within this study, the plant sizing and scheme design has been set with the target that the project maximises CO_2 emissions reductions whilst achieving a positive un-funded project IRR which can be raised to 6%[1] with the use of grant funding within the bounds of state aid limitations[2] .

Cluster	Preferred Technical Solution	LCoH: BaU#1, p/kWh	LCoH: BaU#2, p/kWh	LCoH: DH Scheme, p/kWh	Capital Cost	Intervention required	40-year CO_2 reduction against BaU#1	40-year CO_2 reduction against BaU#2
A	Sewer source heat pump installed in the initial network phase. Closed-loop ground source heat pump installed at later phase. Gas boilers provide peaking and backup generational capacity.	6.63	12.30	9.20	£16.3m	£6.67m HNIP grant	170,000 tonnes; 85% total reduction	5,400 tonnes; 15%
B	Open loop ground source heat pump. Gas boilers provide peaking and backup generational capacity.	9.40	12.53	9.59	£5.5m	£2.08m HNIP grant	12,500 tonnes; 74% total reduction	180 tonnes; 4%%
C	Open loop ground source heat pump. Gas boilers provide peaking and backup generational capacity.	5.04	13.25	10.12	£5.7m	£2.58m HNIP grant	58,000 tonnes; 86% total reduction	190 tonnes; 2% total reduction
D	Open loop ground source heat pump. Gas boilers provide peaking and backup generational capacity.	5.05	11.57	9.75	£1.8m	£0.77m HNIP grant or RHI (GSHP rate)	17,500 tonnes; 87% total reduction	160 tonnes; 6% total reduction
E	Open loop ground source heat pump. Gas boilers provide peaking and backup generational capacity.	7.32	13.43	10.63	£5.0m	£2.23m HNIP grant	20,300 tonnes; 78% total reduction	130 tonnes; 2% total reduction
F	Open loop ground source heat pump. Gas boilers provide peaking and backup generational capacity.	5.86	15.89	8.96	£2.2m	RHI (GSHP rate)	12,100 tonnes; 90% total reduction	30 tonnes; 2%

Table 4-1: Results from the district heating optioneering study for each identified heat cluster

The optioneering analysis has shown that DEN solutions in all clusters:

- When compared to **BaU#1**; the continued use of the existing heating plant;
  - Result in higher whole life cycle heating costs;
  - Reduces CO_2 emissions by between 75 to 90%;
- When compared to **BaU#2**; conversion of existing heating systems to building level ASHPs;
  - Has higher overall capital costs for implementation;
  - Results in lower whole life cycle heating costs;
  - Reduces CO_2 emissions by between 2 to 6%;

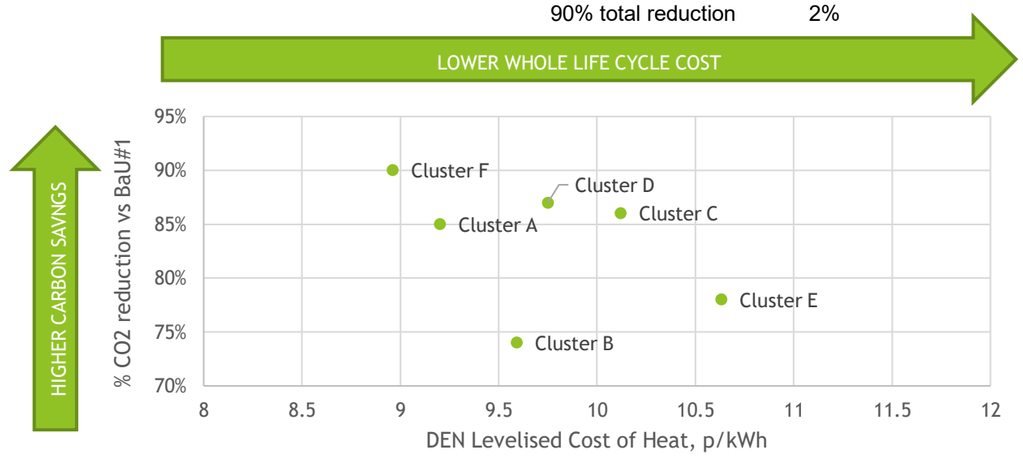


Figure 4-1: The LCoH versus to total % of CO_2 reduction for all clusters

[1] The target IRR value of 6% has been chosen in accordance with the typical internal hurdle rate for investment used by local authorities for energy projects.

[2] State aid limitations have been assumed at a maximum gross grant equivalent contribution of 45% of the total scheme CapEx.

5. Developed Solutions

This section includes the concept designs and key modelling outputs for each cluster.

5.1 Cluster A – Worthing Town Centre

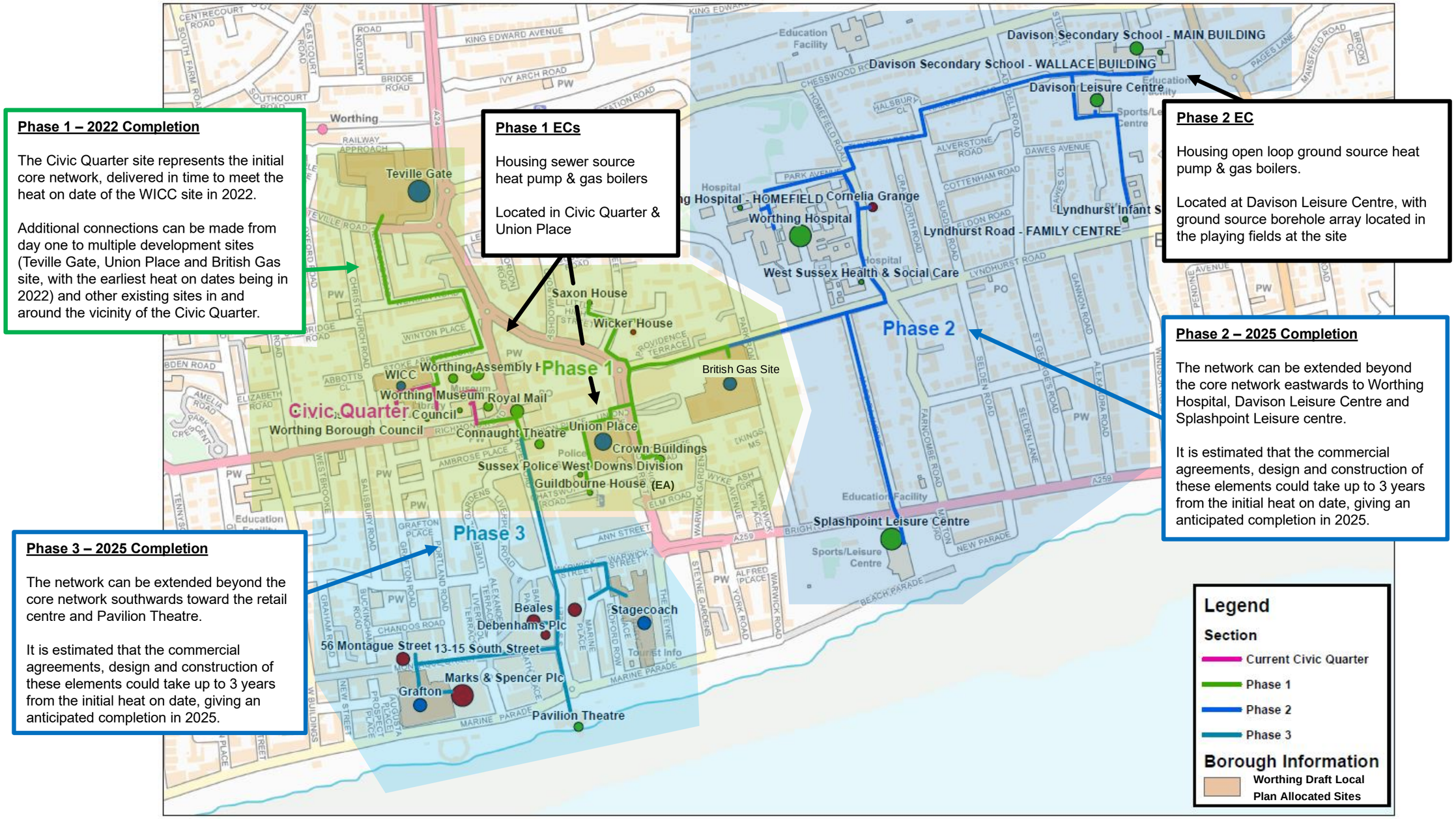

Phase 1 – 2022 Completion
The Civic Quarter site represents the initial core network, delivered in time to meet the heat on date of the WICC site in 2022.
Additional connections can be made from day one to multiple development sites (Teville Gate, Union Place and British Gas site, with the earliest heat on dates being in 2022) and other existing sites in and around the vicinity of the Civic Quarter.
Phase 1 ECs
Housing sewer source heat pump & gas boilers
Located in Civic Quarter & Union Place
Phase 2 EC
Housing open loop ground source heat pump & gas boilers.
Located at Davison Leisure Centre, with ground source borehole array located in the playing fields at the site
Phase 2 – 2025 Completion
The network can be extended beyond the core network eastwards to Worthing Hospital, Davison Leisure Centre and Splashpoint Leisure centre.
It is estimated that the commercial agreements, design and construction of these elements could take up to 3 years from the initial heat on date, giving an anticipated completion in 2025.
Phase 3 – 2025 Completion
The network can be extended beyond the core network southwards toward the retail centre and Pavilion Theatre.
It is estimated that the commercial agreements, design and construction of these elements could take up to 3 years from the initial heat on date, giving an anticipated completion in 2025.
Davison Secondary School - MAIN BUILDING
Davison Secondary School - WALLACE BUILDING
Davison Leisure Centre
Worthing
Teville Gate
Worthing Hospital - HOMEFIELD Cornelia Grange
Worthing Hospital
Lyndhurst Road - FAMILY CENTRE
West Sussex Health & Social Care
Saxon House
Wicker House
Phase 1
Phase 2
Phase 3
British Gas Site
WICC
Worthing Assembly H
Worthing Museum
Royal Mail
Civic Quarter 1
Worthing Borough Council
Connaught Theatre
Union Place
Crown Buildings
Sussex Police West Downs Division
Guildbourne House (EA)
Splashpoint Leisure Centre
Sports/Leisure Centre
Beales
Debenhams Plc
Stagecoach
56 Montague Street
13-15 South Street
Marks & Spencer Plc
Grafton
Pavilion Theatre
Legend
Section
Current Civic Quarter
Phase 1
Phase 2
Phase 3
Borough Information
Worthing Draft Local Plan Allocated Sites

Figure 5-1: Route map showing potential network extension of Civic Quarter network throughout Worthing Town Centre

This developed solution is based upon the following considerations:

- The largest possible SSHP (3MW, based upon the estimated flow within the sewer) is installed at the Union Place site and used as the lead technology;
- A backup CL-GSHP 3MW array, installed either within Homefield Park (adjacent to Worthing Hospital) or within the playing field ground of the Davison Leisure Centre, is used as secondary heat source of low carbon heat;
- Fully resilient backup gas boiler provision is included to ensure security of supply to all sites;
- Capital budget has been allowed for lower the flow and return temperatures within each building in this developed option in the Civic Quarter only (as per the core SSHP scheme developed in the Civic Quarter Feasibility study); and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction.

Parameter	Value
Annual Heat Consumption	29.3 GWh
Peak Heat Demand	11.7 MW
Network Length	4,480m
Temperature Regime	85°C flow & 55°C return
Thermal Demand Density	6.54 MWh/m
Sewer Source Heat Pump Capacity	3 MW
Closed Loop Ground Source Heat Pump Capacity	3 MW
Gas Boiler Capacity	13.7 MW
Total Capital Cost	£16.3 Million
Levelised Cost of Heat (25-year assessment)	9.20 p/kWh
Estimated Commercial User Tariff – 2022[3]	9.04 p/kWh
Estimated Residential User Tariff - 2022	10.76 p/kWh[4]
Grant funding required for 6% IRR	£6.67 million

Table 5-1: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded IRR	-6.40%	-1.77%	0.91%
Project funded IRR (with HNIP)	1.48%	4.30%	6.00%
Carbon savings *in comparison to 'Do Nothing' BaU scenario*	99,814 tonnes; 82.9%	123,180 tonnes; 83.7%	169,911 tonnes; 84.6%
Carbon savings *in comparison to 'Alternative Decarbonisation'' BaU scenario*	3,860 tonnes; 15.85%	4.380 tonnes; 15.50%	5,420 tonnes; 15.02%

Table 5-2: Key network economic and environmental performance factors

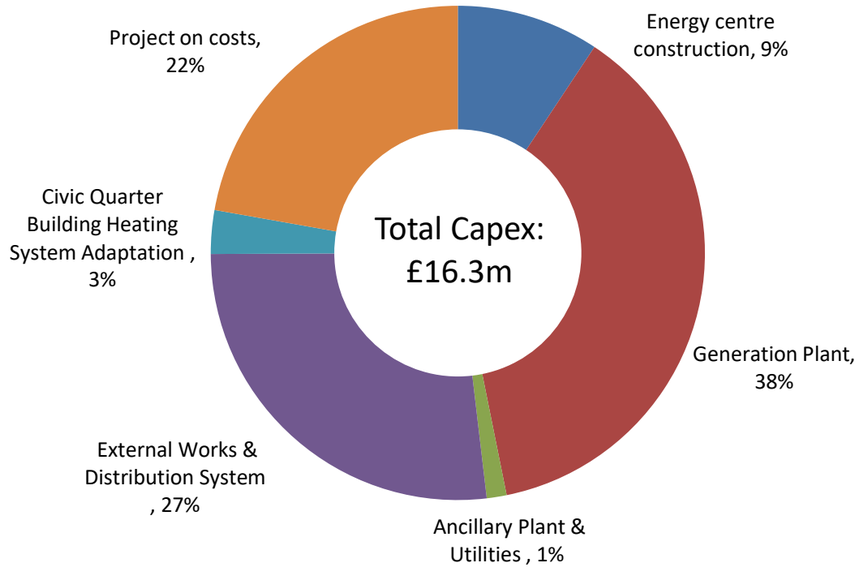

Project on costs, 22%
Energy centre construction, 9%
Civic Quarter Building Heating System Adaptation , 3%
Total Capex: £16.3m
Generation Plant, 38%
External Works & Distribution System , 27%
Ancillary Plant & Utilities , 1%

Figure 5-2: Breakdown of capital costs for Cluster A developed solution

[3] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs. Refer

[4] Set to ensure residential tenants do not pay more than gas boiler generation, as based on the heat trust requirements.

5.2 Cluster B: Worthing Leisure Centre

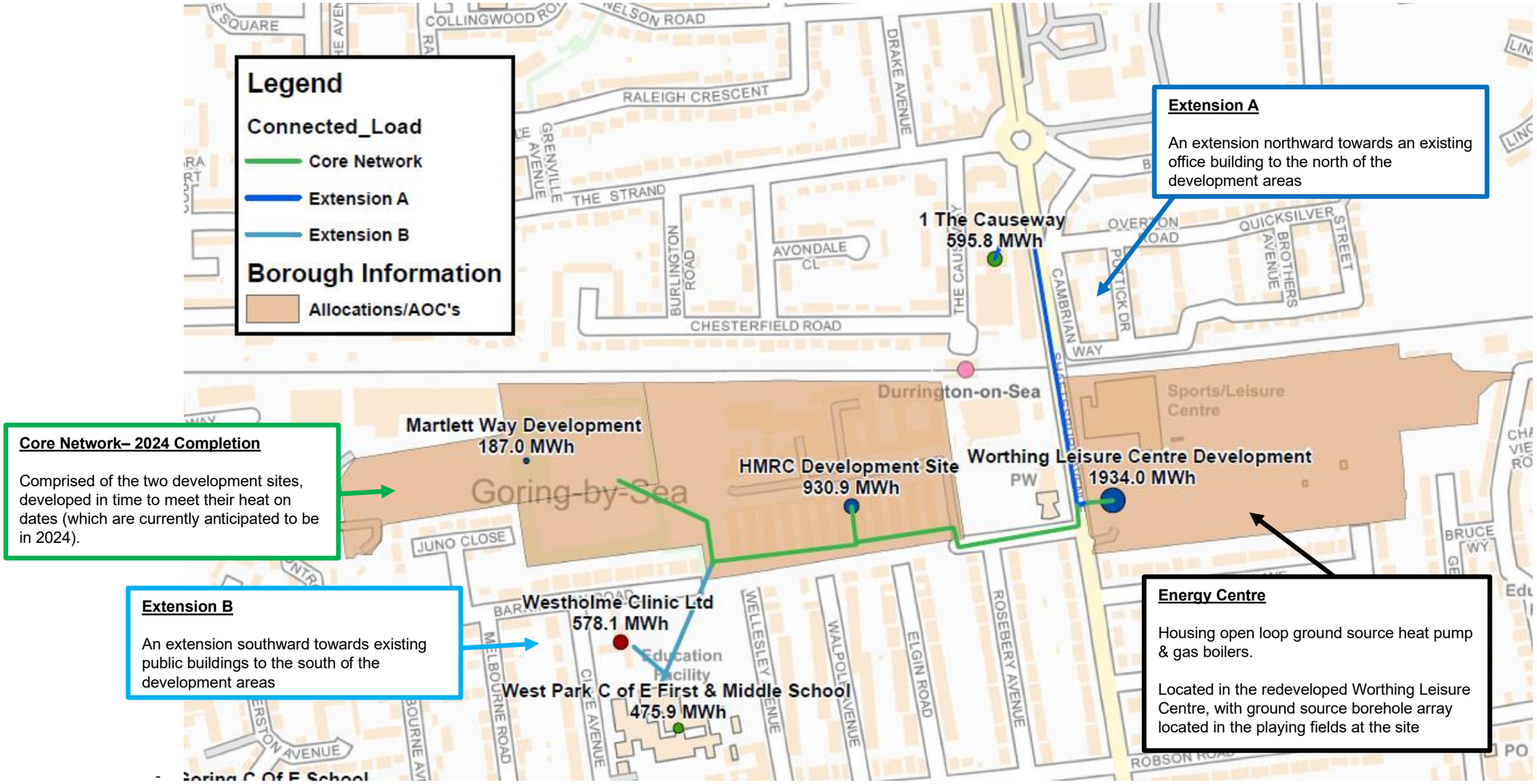


Figure 5-3: Route plan for potential network in Durrington-on-Sea

5.2.1 Developed Scheme

Following on from the optioneering assessment, the developed solution for a DEN in Durrington-on-sea is as follows:

- A 0.95 MW OL-GSHP array, installed in the ground of Worthing Leisure Centre, is lead technology;
- Fully resilient backup gas boiler provision is included to ensure security of supply to all sites;
- A high-level capital budget allowance has been included to lower the flow and return temperatures within each of the existing buildings; and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction.

5.2.2 Developed Solution Details

Parameter	Value
Annual Heat Consumption	5.0 GWh
Peak Heat Demand	2.1 MW
Network Length	1,166 m
Temperature Regime	65°C flow & 35°C return
Thermal Demand Density	4.3 MWh/m
Heat-On Date	2024 (estimated)
Heat Pump Capacity	0.95 MW
Gas Boiler Capacity	2.6 MW
Total Capital Cost	£5.5 Million
Levelised Cost of Heat (25-year assessment)	9.59 p/kWh
Estimated Commercial User Tariff – 2022[5]	9.90 p/kWh
Estimated Residential User Tariff - 2022	11.30 p/kWh[6]
Grant funding required for 6% IRR	£2.08 million [7]

Table 5-3: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded IRR	-1.97%	0.06%	1.86%
Project funded IRR (with HNIP)	3.79%	4.98%	6.00%
Carbon savings *in comparison to 'Do Nothing' BaU scenario*	7,750 tonnes 71.6%	9,330 tonnes; 72.6%	12,500 tonnes; 73.9%
Carbon savings *in comparison to 'Alternative Decarbonisation'' BaU scenario*	181 tonnes; 6.2%	196 tonnes; 5.3%	181 tonnes; 3.9%

Table 5-4: Key network economic and environmental performance factors

[5] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs. Refer
[6] Set to ensure residential tenants do not pay more than gas boiler generation, as based on the heat trust requirements.

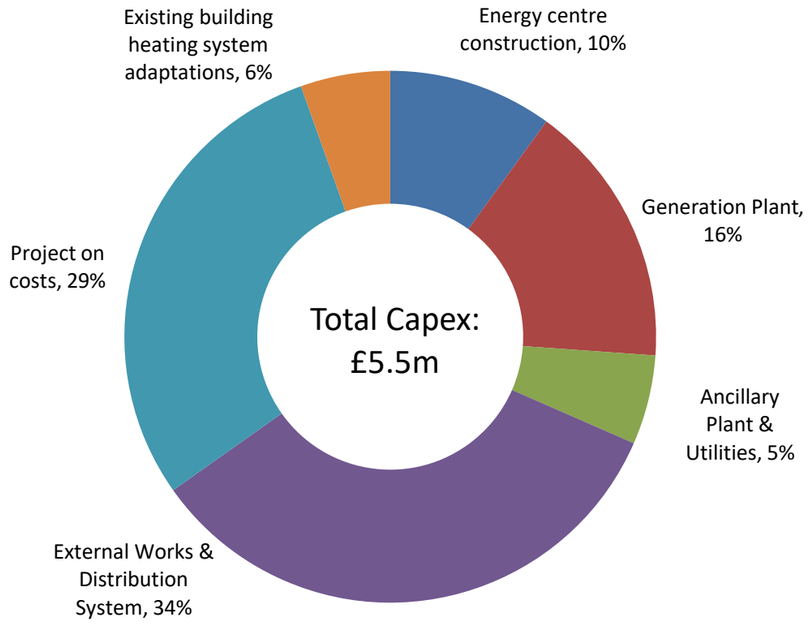

Existing building heating system adaptations, 6%
Energy centre construction, 10%
Generation Plant, 16%
Ancillary Plant & Utilities, 5%
External Works & Distribution System, 34%
Project on costs, 29%
Total Capex: £5.5m

Figure 5-4: Breakdown of capital costs for Cluster B developed solution

5.2.3 Open Loop Ground Source Heat Pump – Borehole Locations

In order to be able to deliver the 0.95MW thermal output modelled, it is estimated that between 2 and 4 borehole couplets would be required. The array arrangement below has been developed to ensure at least 100m between each borehole.

Figure 5-5: Concept design for abstraction and recharge borehole locations

[7] Determined by the anticipated state aid limit of 45% of the total capital cost applicable for HNIP funding, which excludes building internal heating system upgrade works.

5.3 Cluster C: Northbrook College Campus

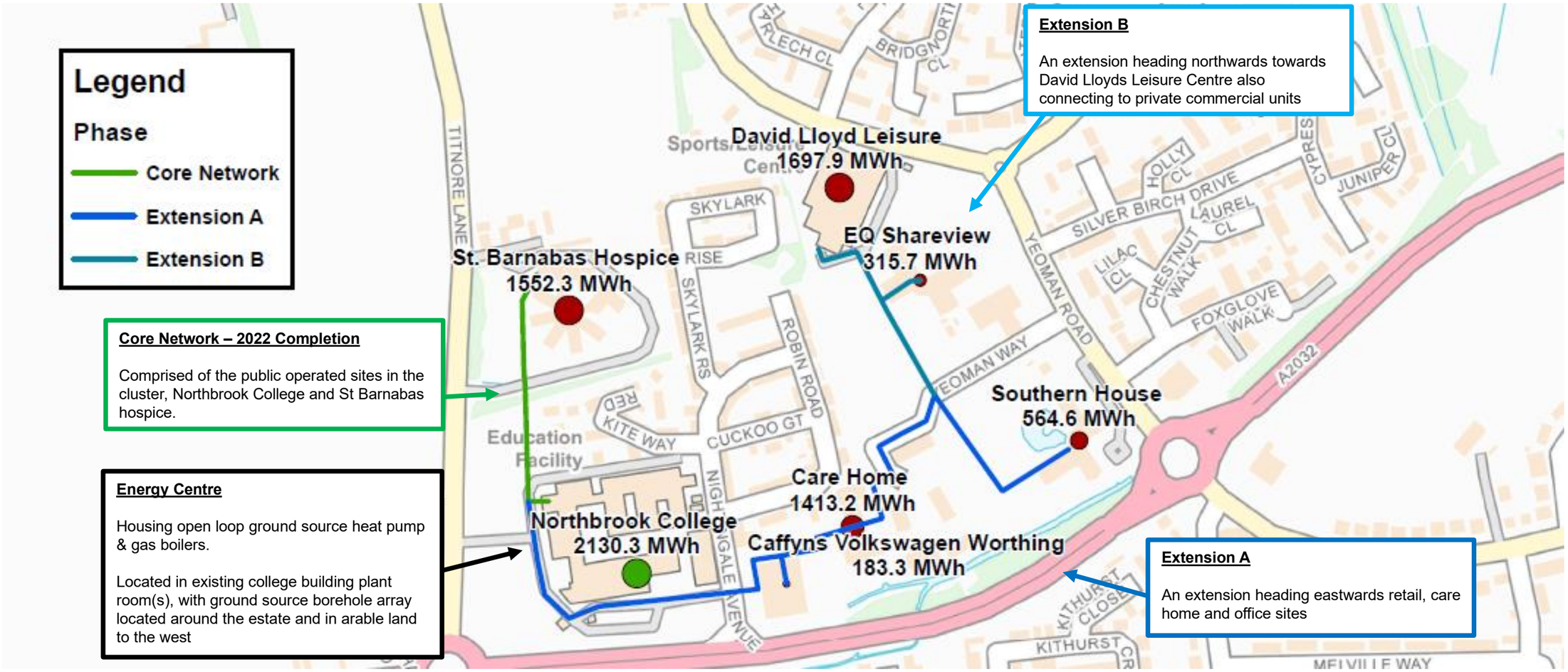


Figure 5-6: Route plan for potential network in Northbrook College Campus

Following on from the optioneering assessment, the developed solution for a DEN for Cluster C is as follows:

- A 1.75 MW OL-GSHP array, installed in the arable land to the west of Northbrook College, is used as the lead technology;
- Fully resilient backup gas boiler provision is included to ensure security of supply to all sites;
- High temperature heat pumps are used to supply heat at the temperatures required by the connected sites (assumed to operate with internal heating system flow and return temperatures of 82/71°C); and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction.

5.3.1 Developed Solution Details

Parameter	Value
Annual Heat Consumption	8.6 GWh
Peak Heat Demand	3.7 MW
Network Length	1,248 m
Temperature Regime	85°C flow & 55°C return
Thermal Demand Density	6.89 MWh/m
Heat-On Date	2022
Heat Pump Capacity	1.9 MW
Gas Boiler Capacity	4.4 MW
Thermal Store Capacity	50m^3
Total Capital Cost	£5.7 Million
Levelised Cost of Heat (25-year assessment)	10.12 p/kWh
Estimated Commercial User Tariff – 2022[8]	10.46 p/kWh
Grant funding required for 6% IRR	£2.58 million[9]

Table 5-5: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded IRR	-3.14%	-0.38%	1.67%
Project funded IRR (with HNIP)	3.38%	4.86%	6.00%
Carbon savings *in comparison to 'Do Nothing' BaU scenario*	35,341 tonnes; 84.25%	42,851 tonnes; 85.13%	57,873 tonnes; 86.23%
Carbon savings *in comparison to 'Alternative Decarbonisation'' BaU scenario*	268 tonnes; 3.89%	242 tonnes; 3.13%	190 tonnes; 2.01%

Table 5-6: Key network economic and environmental performance factors

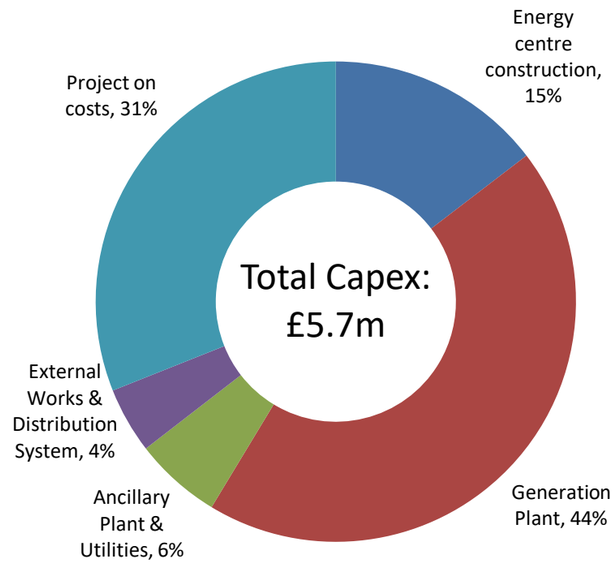

Energy centre construction, 15%
Project on costs, 31%
Total Capex: £5.7m
External Works & Distribution System, 4%
Ancillary Plant & Utilities, 6%
Generation Plant, 44%

Figure 5-7: Breakdown of capital costs for Cluster C developed solution

5.3.2 Open Loop Ground Source Heat Pump – Borehole Locations

In order to be able to deliver the 1.9MW thermal output modelled, it is estimated that between 4 and 6 borehole couplets would be required. The OL-GSHP borehole array arrangement has been developed to ensure at least 100m between each borehole.

Figure 5-8: Concept design for abstraction and recharge borehole locations

[8] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs. Refer

[9] Determined by the anticipated state aid limit of 45% of the total capital cost applicable for HNIP funding, which excludes building internal heating system upgrade works.

5.4 Cluster D: Salvington Hill

Legend
Phase
Core Network
Main building
Salvington Lodge
Wellingham Ln
Salvington Hill
Sussex Pa
Founda
Energy Centre
Housing open loop ground source heat pump & gas boilers.
Located in existing building plant room(s), with ground source borehole array located around the estate
Core Network – 2022 Completion
Network delivered as a single phase serving the whole campus

Figure 5-9: Route Plan for a potential network around the NHS Salvington campus.

Following on from the optioneering assessment, the developed solution for a DEN in Cluster D is as follows:

- A 0.5 MW OL-GSHP array, installed in the NHS campus site, is used as the lead technology;
- Fully resilient backup gas boiler provision is included to ensure security of supply to all sites;
- High temperature heat pumps are used to supply heat at the temperatures required by the connected sites (assumed to operate with internal heating system flow and return temperatures of 82/71°C); and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction.

5.4.1 Developed Solution Details

Parameter	Value
Annual Heat Consumption	2.5 GWh
Peak Heat Demand	0.8 MW
Network Length	350 m
Temperature Regime	85°C flow & 55°C return
Thermal Demand Density	7.14 MWh/m
Heat-On Date	2022
Heat Pump Capacity	0.5 MW
Gas Boiler Capacity	1.1 MW
Thermal Store Capacity	50m^3
Total Capital Cost	£1.7 Million
Levelised Cost of Heat (25-year assessment)	9.75 p/kWh
Estimated Commercial User Tariff– 2022[10]	10.09 p/kWh (if HNIP funding obtained) 8.60 p/kWh (if RHI funding obtained)
Grant funding required for 6% IRR	£0.77 million[11]

Table 5-7: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded IRR	-2.93%	-0.33%	1.71%
Project funded IRR (with HNIP)	3.45%	4.88%	6.00%
Carbon savings *in comparison to 'Do Nothing' BaU scenario*	10,600 tonnes; 84.85%	12.960 tonnes; 85.69%	17.500 tonnes; 86.74%
Carbon savings *in comparison to 'Alternative Decarbonisation'' BaU scenario*	156 tonnes; 7.5%	157 tonnes; 6.8%	159 tonnes; 5.6%

[10] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs. Refer

Table 5-8: Key network economic and environmental performance factors

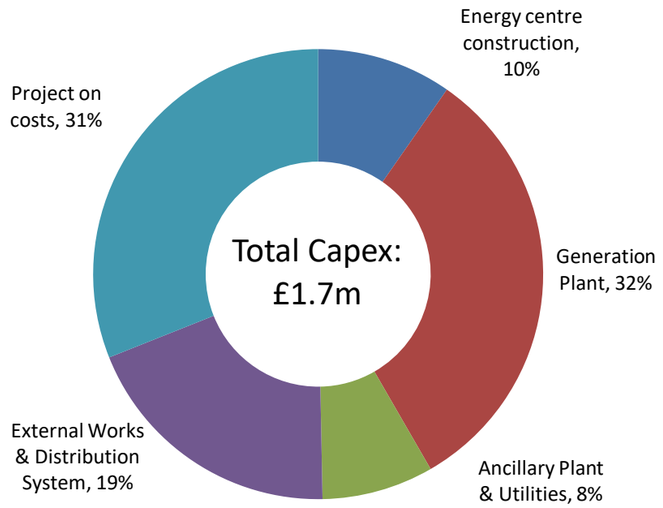

Energy centre construction, 10%
Project on costs, 31%
Total Capex: £1.7m
Generation Plant, 32%
External Works & Distribution System, 19%
Ancillary Plant & Utilities, 8%

Figure 5-10: Breakdown of capital costs for Cluster E developed solution

5.4.2 Open Loop Ground Source Heat Pump – Borehole Locations

In order to be able to deliver the 0.5MW thermal output modelled, it is estimated that between 1 and 2 borehole couplets would be required. The OL-GSHP borehole array arrangement has been developed to ensure at least 100m between each borehole.

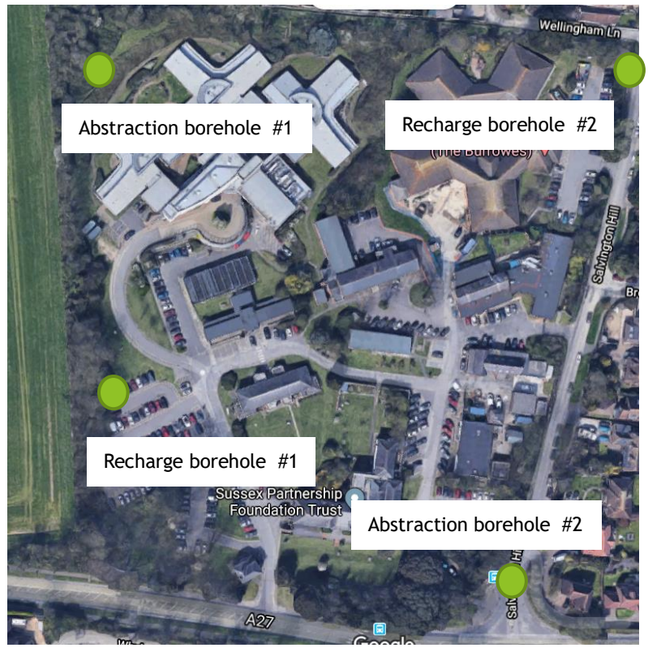


Figure 5-11: Concept design for abstraction and recharge borehole locations

[11] Determined by the anticipated state aid limit of 45% of the total capital cost applicable for HNIP funding, which excludes building internal heating system upgrade works.

5.5 Cluster E: Centenary House

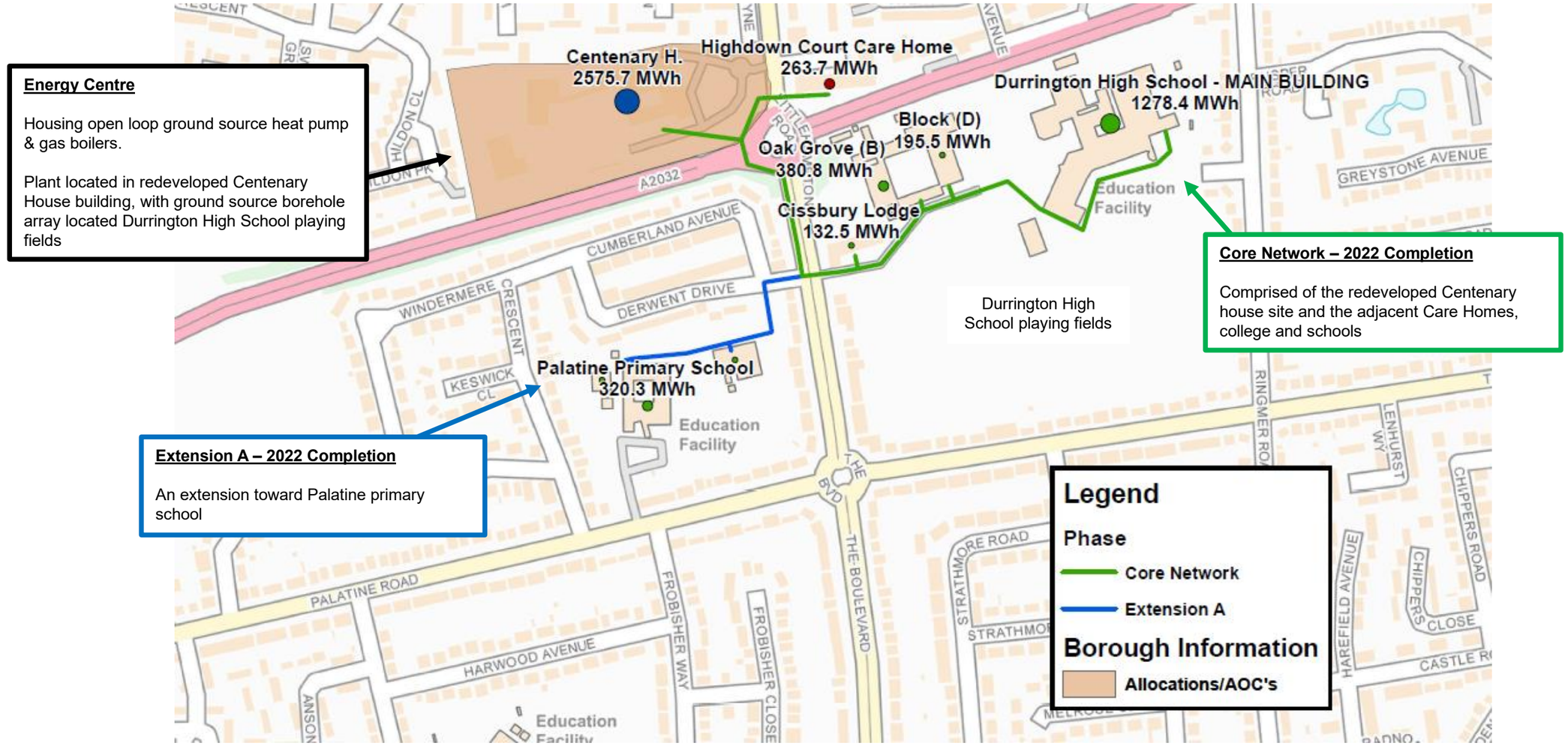


Figure 5-12:Route Plan for a potential network from Centenary House.

Following on from the optioneering assessment, the developed solution for a DEN in Cluster E is as follows:

- A 1.7 MW OL-GSHP array, installed in the Durrington High School playing fields, is the lead technology;
- Fully resilient backup gas boiler provision is included to ensure security of supply to all sites;
- High temperature heat pumps are used to supply heat at the temperatures required by the connected sites (assumed to operate with internal heating system flow and return temperatures of 82/71°C); and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction.

5.5.1 Developed Solution Details

Parameter	Value
Annual Heat Consumption	5.8 GWh
Peak Heat Demand	3.2 MW
Network Length	1,180 m
Temperature Regime	85°C flow & 55°C return
Thermal Demand Density	4.9 MWh/m
Heat-On Date	2022
Heat Pump Capacity	1.7 MW
Gas Boiler Capacity	3.9 MW
Thermal Store Capacity	100m^3
Heat Split – Heat Pump / Boiler	99% / 1%
Total Capital Cost	£5.0 Million
Levelised Cost of Heat (25-year assessment)	10.63 p/kWh
Estimated Commercial User Tariff – 2022[12]	10.86 p/kWh
Grant funding required for 6% IRR	£2.23 million[13]

Table 5-9: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded IRR	-5.91%	-1.61%	0.88%
Project funded IRR (with HNIP)	3.04%	4.78%	6.00%
Carbon savings *in comparison to 'Do Nothing' BaU scenario*	12,388 tonnes; 75.48%	15,041 tonnes; 76.87%	20,346 tonnes; 78.64%
Carbon savings *in comparison to 'Alternative Decarbonisation'' BaU scenario*	96 tonnes; 2.3%	107 tonnes; 2.3%	129 tonnes; 2.3%

Table 5-10: Key network economic and environmental

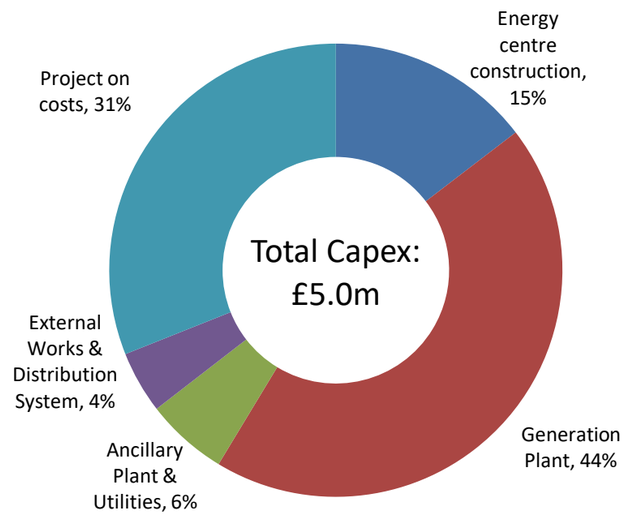

Energy centre construction, 15%
Project on costs, 31%
Total Capex: £5.0m
External Works & Distribution System, 4%
Ancillary Plant & Utilities, 6%
Generation Plant, 44%

Figure 5-13: Breakdown of capital costs for Cluster E developed solution

5.5.2 Open Loop Ground Source Heat Pump – Borehole Locations

In order to be able to deliver the 1.7MW thermal output modelled, it is estimated that between 3 and 5 borehole couplets would be required. The OL-GSHP borehole array arrangement has been developed to ensure at least 100m between each borehole.

Figure 5-14: Concept design for abstraction and recharge borehole locations

[12] Note, a small degree of tariff escalation is modelled in line with the BEIS projected real price escalation of electricity sale tariffs. Refer

[13] Determined by the anticipated state aid limit of 45% of the total capital cost applicable for HNIP funding, which excludes building internal heating system upgrade works.

5.6 Cluster F: Northbrook Central Campus

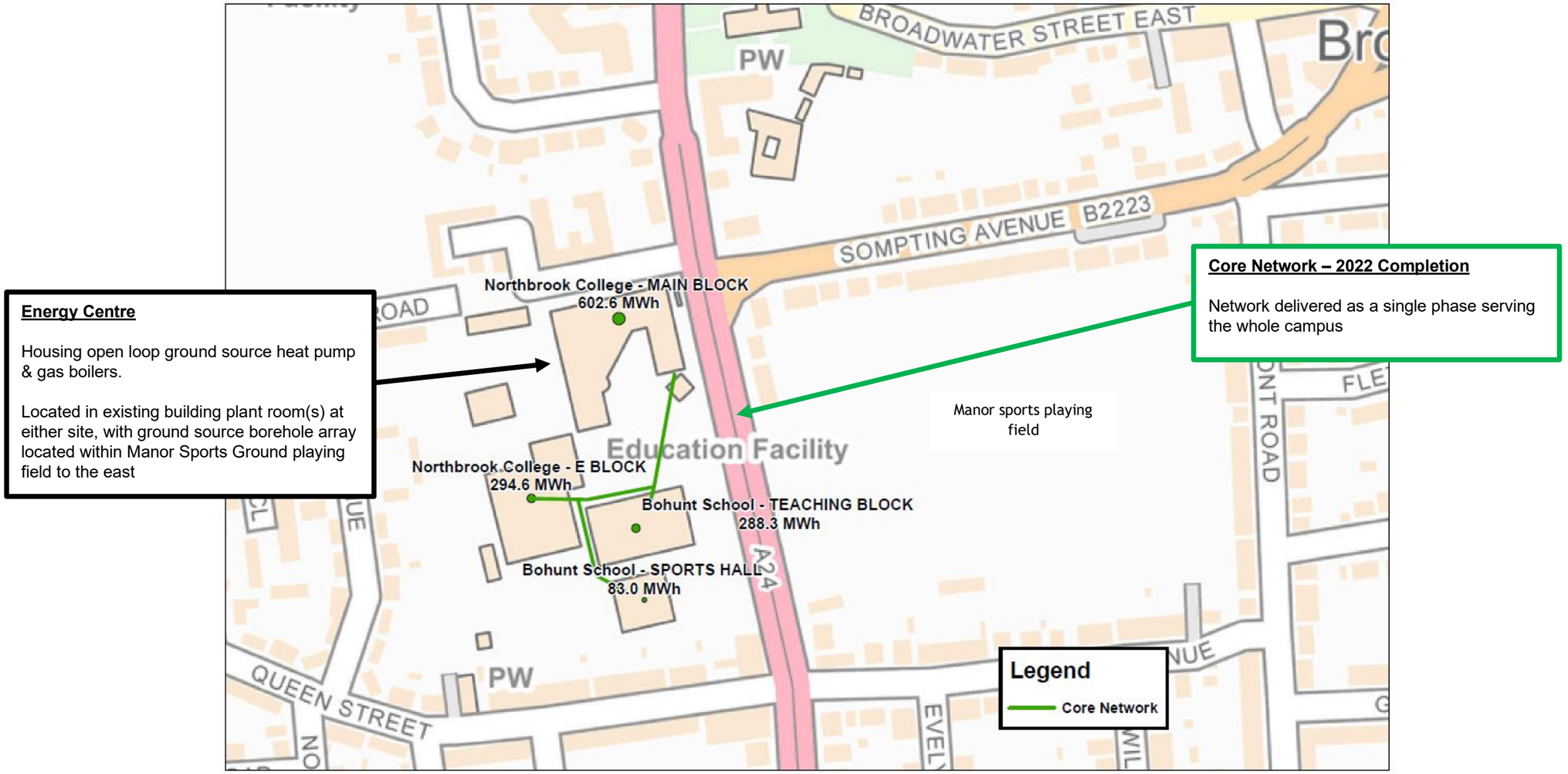

Energy Centre
Housing open loop ground source heat pump & gas boilers.
Located in existing building plant room(s) at either site, with ground source borehole array located within Manor Sports Ground playing field to the east
Core Network – 2022 Completion
Network delivered as a single phase serving the whole campus
Manor sports playing field
BROADWATER STREET EAST
SOMPTING AVENUE
B2223
PW
Northbrook College - MAIN BLOCK
602.6 MWh
Education Facility
Northbrook College - E BLOCK
294.6 MWh
Bohunt School - TEACHING BLOCK
288.3 MWh
Bohunt School - SPORTS HALL
83.0 MWh
A24
QUEEN STREET
Legend
Core Network

Figure 5-15:Route plan for a small network connecting the Bohunt School and Northbrook College Sites.

Following on from the optioneering assessment, the developed solution for a DEN in Cluster F:

- A 0.7 MW OL-GSHP array, installed in the Manor Sports Playing Ground is sufficiently large to house the required equipment.
- Fully resilient backup gas boiler provision is included to ensure security of supply to all sites;
- Low temperature heat pumps are used to supply heat at the temperatures required by the connected sites (assumed to be adaptable to operate with internal heating system flow and return temperatures of 60/30°C); and
- The commercial heat tariff has been set by the model to determine the required revenue to achieve the lowest possible CO_2 reduction.

5.6.1 Developed Solution Details

Parameter	Value
Annual Heat Consumption	1.7 GWh
Peak Heat Demand	1.7 MW
Heat-On Date	2022
Network Length	190 m
Temperature Regime	65°C flow & 35°C return
Thermal Demand Density	8.94 MWh/m
Heat Pump Capacity	0.7 MW
Gas Boiler Capacity	2.1 MW
Thermal Store Capacity	50m^3
Total Capital Cost	£2.2 Million
Levelised Cost of Heat (25-year assessment)	8.96 p/kWh (with RHI) 14.56 p/kWh (no RHI)
Estimated Commercial User Tariff (2022)	11.69 p/kWh (with RHI) 16.85 p/kWh (no RHI)

Table 5-11: Key network parameters for the developed SSHP solution

	25-year Assessment	30-year Assessment	40-year Assessment
Project unfunded IRR	-6.77%	-2.29%	0.33%
Project funded IRR (with RHI)	4.91%	5.46%	6.00%
Carbon savings *in comparison to 'Do Nothing' BaU scenario*	7,458 tonnes' 87.97%	90,020 tonnes; 88.66%	12.145 tonnes' 89.54%
Carbon savings *in comparison to 'Alternative Decarbonisation'' BaU scenario*	36 tonnes; 3.4%	34 tonnes: 2.8%	30 tonnes; 2%

Table 5-12: Key network economic and environmental performance factors

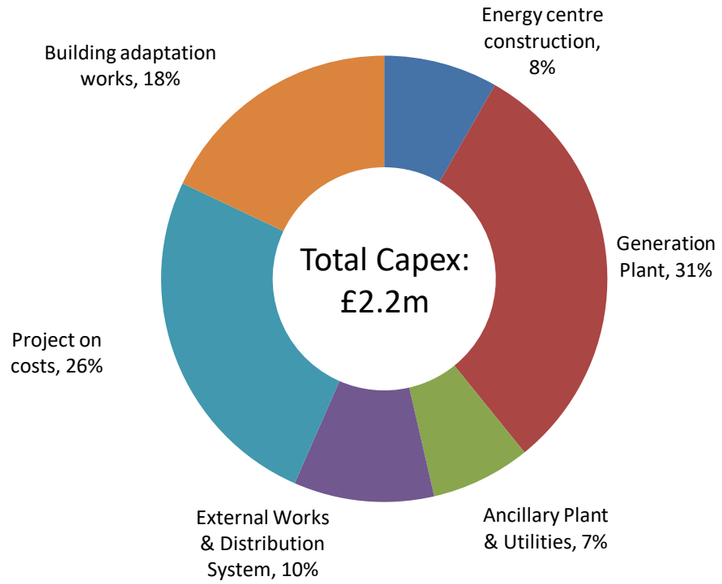

Energy centre construction, 8%
Building adaptation works, 18%
Total Capex: £2.2m
Generation Plant, 31%
Project on costs, 26%
External Works & Distribution System, 10%
Ancillary Plant & Utilities, 7%

Figure 5-16: Breakdown of capital costs for Cluster F developed solution

5.6.2 Open Loop Ground Source Heat Pump – Borehole Locations

In order to be able to deliver the 0.7MW thermal output modelled, it is estimated that between 2 and 3 borehole couplets would be required. The OL-GSHP borehole array arrangement has been developed to ensure at least 100m between each borehole.

Figure 5-17: Concept design for abstraction and recharge borehole locations

6. Conclusions

Based on the above analysis, AECOM's conclusion is that there is good potential for delivering low-carbon heat network solutions at each within all the identified building clusters in Worthing Borough.

6.1 Technical

6.1.1 Thermal Generation Technology

This study has assumed that there are for each cluster multiple different heat pump solutions that could be developed, with the optimal solutions being comprised of:

- **A sewer source heat pump**, which can be developed within Worthing Town Centre (**Cluster A**), with the either of new development sites of 'Union Place' or 'Stagecoach' presenting an ideal opportunity to install the required infrastructure given their adjacency to the main sewer line.

  As identified within the Civic Quarter feasibility study, the capital costs for installing SSHP at small scale result are relatively high in comparison to other solutions. However, as it is estimated that there is the opportunity to recovery a significant amount of heat from a single location (up to 3MW), this solution becomes the most cost-effective at large scale, and has therefore been identified as the optimum technical solution for this area.

- **Open loop ground source heat pumps**, which are anticipated to be viable in **all clusters** due the presence of the subterranean aquifer beneath the entire borough.

  In Cluster A there is the potential solution for a small-scale OL-GSHP system, limited to meeting the demands of the Civic Quarter only, with the boreholes being installed on-site within the development boundaries of the Worthing Integrated Care Centre. However, a system of large enough scale to be a significant contributor to a larger network serving the entire Worthing Town Centre is not likely to be possible until the network expands away from the dense urban town centre towards areas of open land that lie within WBCs control, with the Davison Leisure Centre playing fields offering such an opportunity. This has therefore been identified as an optimum additional technology which could be developed once the capacity of the SSHP has been maximised;

  In all other clusters the system was identified as the optimal solution, primarily due to installations of suitable capacities to being able to be installed in either arable farmland, sports fields or within large private estates. In each case, the required infrastructure can be installed such that it does not prevent the continued use of any of the sites as per their current purposes.

6.1.2 Distribution Network

None of the analysed clusters were identified as having significant constraints that could prevent the development of a DH network routing between the identified buildings although further detailed work would be required to properly assess and confirm this.

Furthermore, many of the clusters also benefitted from the presence of new development sites, which could reduce the level of intrusive civil works and subsequent costs of implementation.

6.1.3 Lowering Building Internal Heating Temperatures

The Civic Quarter feasibility report identified the potential economic and environmental benefit that could arise from the lowering of heating system temperatures in each building in the Civic Quarter. Doing so would result in the potential to operate the DEN systems at lower temperatures, resulting in higher heat-pump generational efficiencies, with the reduction in annual operational costs shown to outweigh that of the initial capital costs to implement such changes.

Across the other clusters it has been assumed that the design of any new developments can be tailored to incorporate the system(s) required to operate with lower system temperatures. In those clusters where the majority of the load comes from these new sites it has been assumed that adaptation works could be undertaken on any existing sites in the cluster in order to allow for the whole DEN system to operate at a lower temperature range.

The costs of implementing these proposed alterations have been included within the cost plan for the DEN, with resultant costs arising from high-level estimates using industry standard cost benchmarks.

Should WBC wish to proceed with the intention of including this element of work within the project, and all building stakeholders are happy proceed with undertaking the appropriate measures, more detailed studies would be required to confirm the measures, costs, viability and benefits in each location to inform a business case for investment.

6.2 Environmental

All the developed solutions have been designed to reduce the resultant CO_2 emissions arising from the provision of heating by:

- Up to 90% against the continued use of gas boilers; and
- Up to 5% against the alternative decarbonisation scenario in which all buildings convert their current heating systems to air source heat pumps.

It can therefore be concluded that DEN systems have been shown to represent the best solution at reducing CO_2 emissions from heating systems across the borough.

All developed solutions rely on the continued decarbonisation of the UK-electrical grid, which is not anticipated to become fully carbon neutral until circa 2050. Therefore, to achieve carbon neutral operation of the WBC / A&WC building stock by their 2030 target, additional off-site carbon offsetting measures will need to be implemented in the intervening period.

6.3 Economic

All the solutions analysed were shown to:

- increase the heating costs for all customers against their present-day business as usual scenario, which for existing buildings is the use of gas boilers; but
- offer a cheaper route to heating system decarbonisation when compared against building-level heat pump installations.

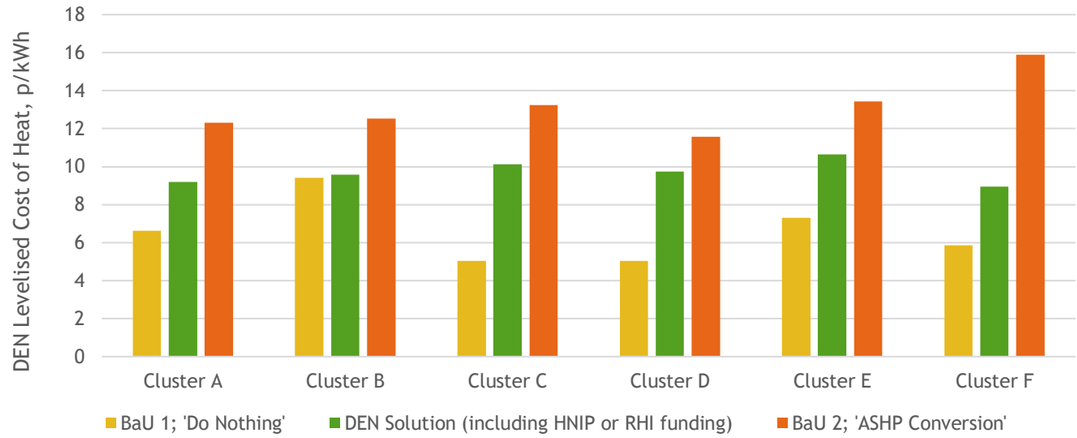


Figure 6-1: Comparison of the levelised cost of heat under the two BaU scenarios and the developed DEN solutions

Figure 6-1 illustrates that:

- the DEN solution for Clusters A has one of the lowest overall levelised costs of heat, as it is the largest network and benefits from economies of scale associated with the plant and infrastructure elements.
- Cluster B is the most competitive against the Do Nothing BaU as a large proportion of the connected sites are new developments which would be conditioned to install ASHPs anyway; and
- Cluster F offers the largest saving against the ASHP conversion, assuming it can be delivered in a short enough timeframe to obtain RHI funding.

It is not likely the cost of the use of boilers will continue in the manner that it does currently. Figure 6-2 below illustrates the different levels of heat tariff rates paid by buildings within the Civic Quarter area of Cluster A, and a potential tariff escalation scenario based upon the implementation of policy drivers.

Against this realistic 'do nothing' business as usual scenario, the implementation of DENs can be shown to offer lower whole life cycle costs.

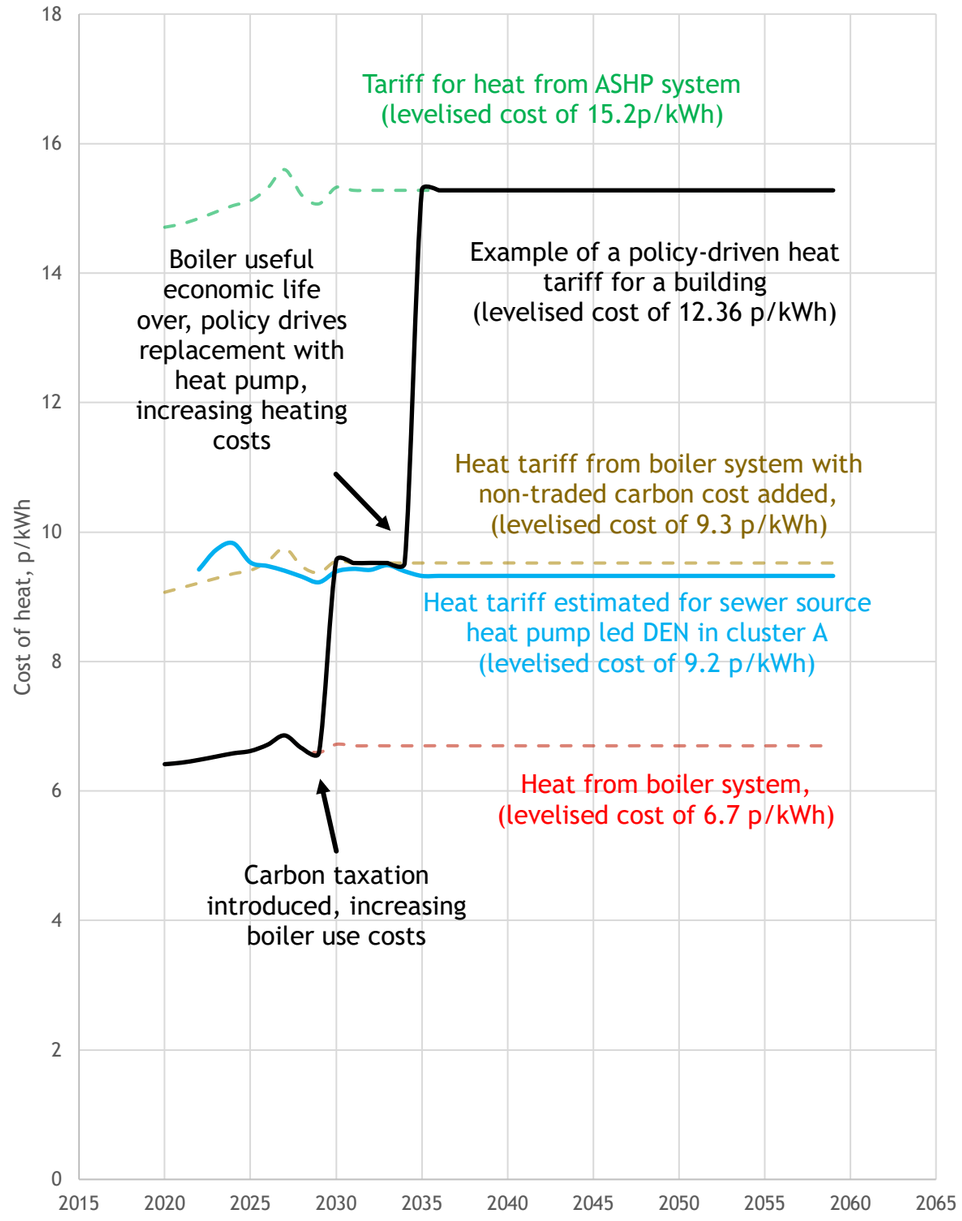


Figure 6-2: A potential resultant long-term 'business as usual' heat tariff scenario compared against developed district heating solution for Cluster A

6.4 Funding Routes

At the time of writing, two UK-treasury financed grant funding schemes are operational which are applicable to the proposed DEN scheme.

Once the level of funding required to achieve the chosen solution has been identified, a funding application can be made.

6.4.1 Heat Networks Investment (HNIP) Programme

All the developed solutions identified within this report have estimated unfunded project-IRRs that are likely to be lower than that required by WBC for investment purposes. This is typical of DEN projects across the county and is what the Heat Networks Investment Programme (HNIP) was set up to address. Its purpose is to distribute grant funding and low-interest loans (paid by the UK Treasury) to DEN projects that require a level of gap-funding to be considered economically attractive enough to attract the capital investment required to deliver them.

6.4.2 Renewable Heat Incentive (RHI)

All the developed solutions identified within this report are also eligible for the RHI scheme, which provides an additional revenue stream based upon the amount of thermal energy generated by a heat pump system operating above at high efficiency. The incentives last for 20 years following the first payment date, and at the time of writing the scheme is due to cease in March 2022, at which point any system is required to be both operational and delivering heat to one or more customers in order to be eligible.

It has been assumed that only network of a small scale or including only a very small number of potential heat customers (i.e. clusters D or F) would be able to deliver a scheme fast enough to achieve this cut-off date.

6.5 Planning policy

The development of heat networks across Worthing can be supported by planning policy requiring new developments to connect to existing or planned heat networks where feasible or, in locations where the opportunity to deliver a heat networks has been identified, incorporate measures to enable future connection.

Examples of this include the London Plan[14] which uses a heat hierarchy to prioritise connection to existing heat networks above individual building heating systems and also provides guidance[15] to developers on designing plant rooms and heating systems to facilitate future connection.

This report, by identifying specific opportunities for delivering heat networks and undertaking the analysis to demonstrate their potential viability, could be used as an evidence base to support similar policy being incorporated in the Local Plan or supporting DPD/SPD documents and its enforcement through the planning system.

[14] https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan/london-plan-chapter-five-londons-response/pol-22

[15] https://www.london.gov.uk/sites/default/files/london_heat_map_manual_2014.pdf

7. Recommendations & Next Steps

7.1 Summary

In order to decarbonise the existing building stock within the Worthing area in accordance with the carbon commitments made by A&WC, significant investment will be required to replace gas boilers with a low carbon alternative. Given the anticipated continued decarbonisation of the UKs electrical grid prior to this date, the utilisation of heat pump systems can facilitate this transition. The aim of this heat mapping and masterplanning study was to qualitatively and quantitively assess whether heat pump led district energy schemes can viably and sustainably facilitate this transition.

Six building clusters suitable for DENs were identified across the borough. Analysis has shown that in all cases a heat network could deliver:

- A positive, fundable project rate of return whilst offering a discounted capital and operational cost solution to customers (against heat pump conversions within each building);
- A high reduction in CO_2 emissions in comparison to current gas boilers and individual building level ASHP installations;

Furthermore, the heat networks could deliver numerous other local area and social benefits, namely:

- A significant improvement in local air quality;
- The ability to speed up the uptake of decarbonised heating systems in the area, delivering significantly higher CO_2 savings compared to a slower building by building approach;
- Increased local energy resilience;
- Significantly lower impact on local power networks compared to individual building heat pumps;
- Local investment and jobs; and
- A clear demonstration from WBC and partners to act on their climate emergency declarations and carbon neutral target.

7.2 Next Steps & Key Risk items for Development

In order to further progress the development of any scheme, the following aspects need to be investigated:

- All identified key loads (such as Worthing Hospital in Cluster A) approached to ascertain their current energy demands and carbon agendas, and their likely appetite to connect in either the short or long terms;
- Techno-economic feasibility analysis confirming that the proposed solutions are viable at both the scale and cost presented within this report;
- The identification of a preferred procurement and ownership structure for any developed scheme.
    - For clusters that are comprised of a small amount of heat customers (D and F), this could include engaging with the identified organisations to highlight the potential to install plant in the short term to make use of Renewable Heat Incentive funding prior to the cessation of the scheme; or
    - For clusters that include many different heat customers (A, B, C & F), this could include investigations and/or soft market testing into the potential source(s) of investment funding required to provide the required capital for the scheme (including access to governmental grant funding, i.e. the Heat Networks Investment Programme).
- Development of the technical solution to de-risk the solution, primarily relating to:
    - Investigations into the technical feasibility of the proposed thermal generation and distribution systems, including gaining the required environmental permits; and
    - Investigations into the optimal network routes.

Appendix A – Illustrative Overview of Heat Networks

The figure below helps illustrate the structure of a typical heat network, identifying some of the key terminology used throughout the report.

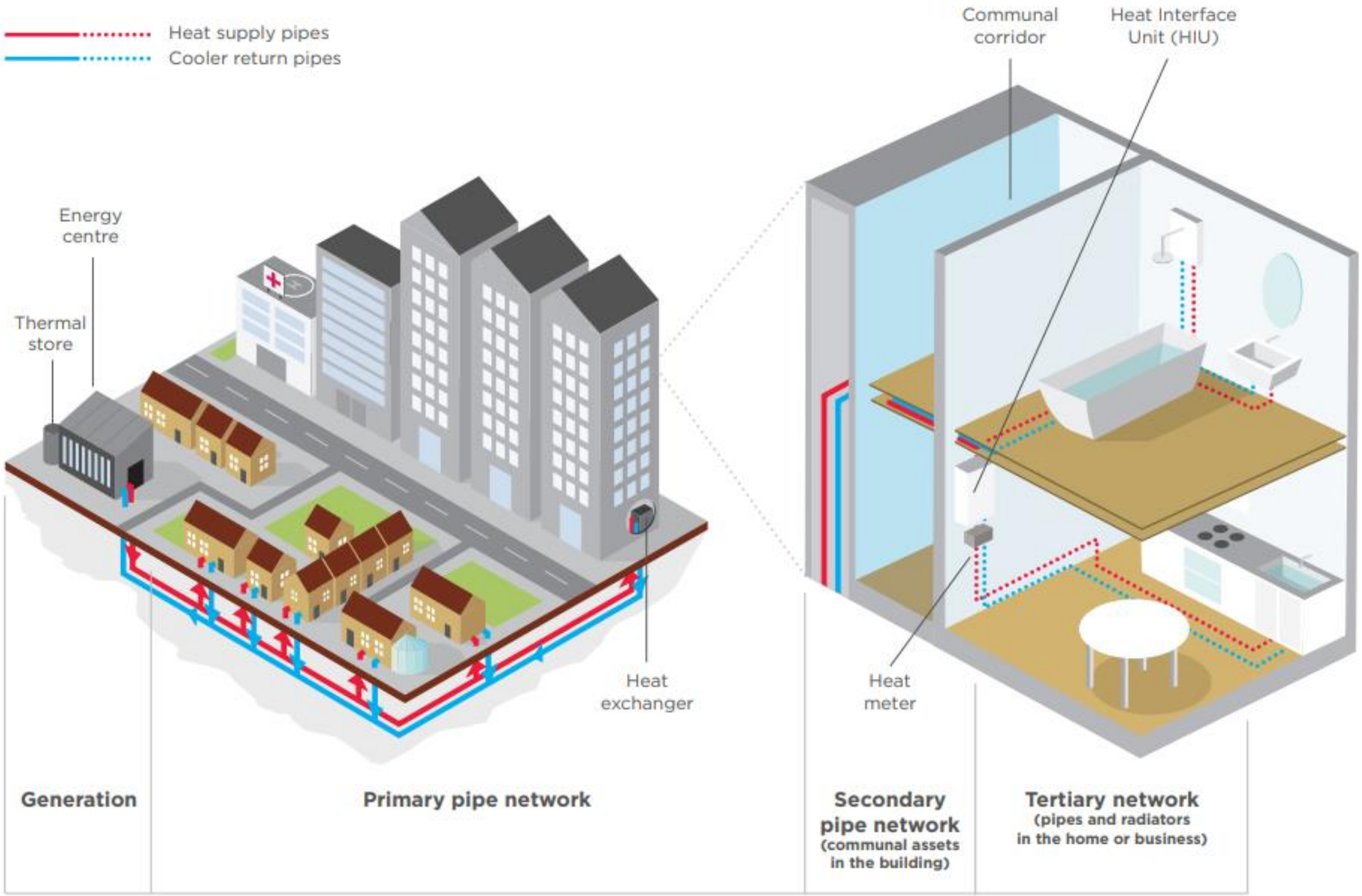


Figure A-1: Illustrative Overview of Heat Networks

Appendix B – Energy Load Information

B.1 Heating demand

For heat networks to be financially viable, significant heat demand is required to justify the capital expense of installing the required pipework to distributed heating between buildings. Therefore, it is important to identify clusters of buildings with a high density of heating demand.

Heat demand within the Worthing Borough boundaries using Display Energy Certificates (DEC's), non-domestic Energy Performance Certificate's (EPC's) and development information obtained from the town's 2016 draft Local Plan. Broadly speaking DEC data is more accurate as it is based on recorded energy consumption. It captures public sector buildings such as schools, leisure centres and hospitals. A boiler efficiency of 89% has been assumed.

Conversely non-domestic EPC's are generally undertaken by private sector buildings. They have been filtered to remove smaller buildings using a threshold of 1,000m^2 GIA. EPC and development site heating estimated heating consumption is less accurate as it based on per square meter benchmarks for each building use type.

Buildings where the heating systems are unlikely to be compatible with district heating are not included in this map. This includes sites where their primary heating fuel is electricity and smaller industrial units.

Public sector buildings and development sites present better opportunities for the installation of heat networks due to WBC's ability to influence their energy strategy. Clusters have been identified where there is significant heat demand (>1 GWh) and multiple buildings in proximity. To put this in context, the proposed Civic Quarter Network, which is comprised of 7 separate facilities, has a total heating demand of roughly 2 GWh per annum.

Table: B1-1 Heat demand benchmarks applied to buildings where only Non-domestic EPC data is available. These are based on CIBSE Guide F benchmarks.

Building Use type	Benchmark heat demand (kWh/m^2/year)
Residential	158
School	86
Community centre	100
Office	78
Museum	84
Hospital	321
Nursing home	354
Leisure centre	211
Entertainment hall	336
Hotel	177
Retail	155
Storage	64

N.B. not all benchmarks are utilised within this study and are displayed primarily for comparative purposes.

Energy demand for development sites has been estimated from the energy statement for the site (Terville Gate and Union Place) or it has been built up using the proposed development usage categories (leisure, commercial or residential) outlined in the Worthing Local Plan. The benchmarks used to estimate the heat demand for these sites differs from those presented above due to the improved building efficiency for new developments. The exception to this was the Worthing Leisure Centre, where limited information was presented in the local plan, it was assumed a facility similar to the Splashpoint leisure centre would be built but with and improvement in efficiency of 20%.

Table B1-2: Heat demand benchmarks used for new developments.

Type	Heat (kWh/m^2/year) Benchmark	Source
Residential	49	SAP
School	21	Model
Community centre	21	Model
Office	22	Model
Museum	94	Guide F
Leisure centre	199	Model
Hotel	198	Model
Retail (Retail Park Unit)	33	2015 GLA
Retail (Within Resi Block)	15	SAP

B.2 Cooling load estimation

The cooling loads within the borough have been estimated using a similar methodology to the heat loads. Where DEC's and EPC's indicate that there is cooling present, they have been estimated using per m^2 benchmarks. These benchmarks were developed for a previous AECOM heatmapping and masterplanning study through the development of building energy models.

Table B2-1: Cooling demand benchmarks used for new developments

Type	Cooling Benchmark (kWh/m^2/year)
School	7
Community centre	7
Office	20
Nursing home	21
Entertainment hall	44
Hotel	5

Appendix C – Generation Plant Appraisal

C.1 Ground Source Heat Pump

A Closed Loop GSHP system collects shallow ground energy held within the soil. The system incorporates an array of boreholes, typically 150m deep, within which plastic pipes are installed. In order to extract the energy, a working fluid mixture of water and glycol is pumped through these plastic pipes, which is heated or cooled (as required) as it is pumped through the buried pipework. Based on local borehole data provided by the Environment Agency and work undertaken as part of the Civic Quarter feasibility study, a single borehole couple (comprised of one abstraction borehole and one recharge borehole) could yield between 5 and 7 litres/ second, equating to circa a 350kW thermal output system.

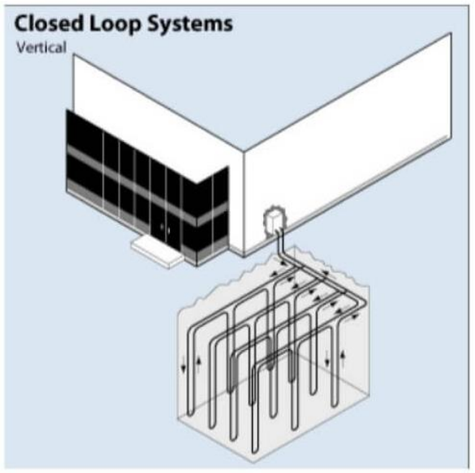


Figure C1-1: Overview of a closed loop ground source heat pump

An Open Loop GSHP scheme typically involves the abstraction of groundwater from one or more boreholes which is then passed through a heat exchanger where heat is either extracted or added to the water, depending on whether the scheme is in a heating or cooling mode, and then discharged through another borehole or boreholes to the same aquifer as the abstracted water.

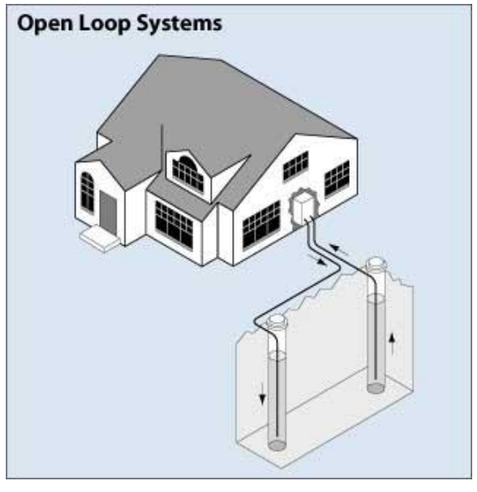


Figure C1-2: Overview of an open loop ground source heat pump

C.2 Sewer Source Heat Pump

The wastewater within the sewer systems contains latent thermal energy, particularly sewage due to heated water discharge from showers, washing machines and other appliances. This heat is captured by abstracting and passing a percentage of the wastewater flow in any given sewer through a plate-heat exchanger assembly, which is specially designed to account for the nature of the fluid, prior to reinjection back into the sewer.

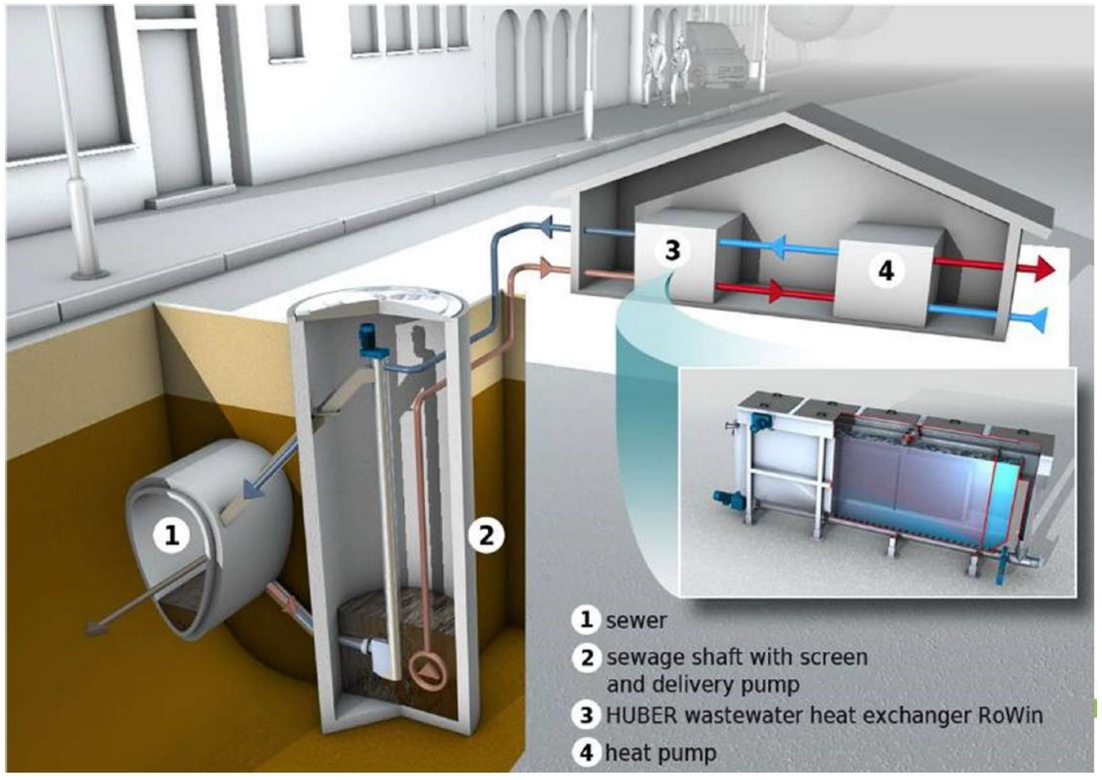


Figure C2-1: Overview of Landmark / Huber's technical solution. Note that alternative systems are commercially available.

Based on flow data provided by Southern Water and work undertaken as part of the Civic Quarter feasibility study, the identified main line sewer in Worthing Town Centre (running eastward to the water treatment plant) contains sufficient flow to power a 3MW thermal output system.

C.3 Marine Source Heat Pump

Marine source heat pumps collect ambient heat stored in sea water.

To abstract the required quantity of sea water, an open loop system is typically use, with a pipeline required to abstract the sea water prior to it passing through a heat exchanger (tailored to operate with saline water) prior to being rejected back out to sea.

The system operated much in the same way as an open-loop GSHP system, however the water abstraction system would likely be highly bespoke to every project as it is very much based upon the geographical conditions of the site.

Existing or planned commercial scale projects in the UK have been designed to utilise existing sea-based infrastructure, such as the marina (as per the Brighton Marina Phase 2 development) or a port (as per the Shoreham Harbour heat network project). The only existing sea-based structure in Worthing is the Victorian-era grade-II listed pier (opened in 1862), the use of which is assumed (at this stage) to represent too high a technical risk based upon the age of the structure. Further detailed analysis is required to ascertain the viability of the use of this structure to house any water abstraction equipment for use in MSHP system.

The preferred solution is therefore an entirely new shore-based system, where the pipework is installed below ground level and abstracts sea water from a fixed distance away from the shoreline that ensures tidal affects do not curtail system function. This type of system is common within the de-salination water treatment plant industry.

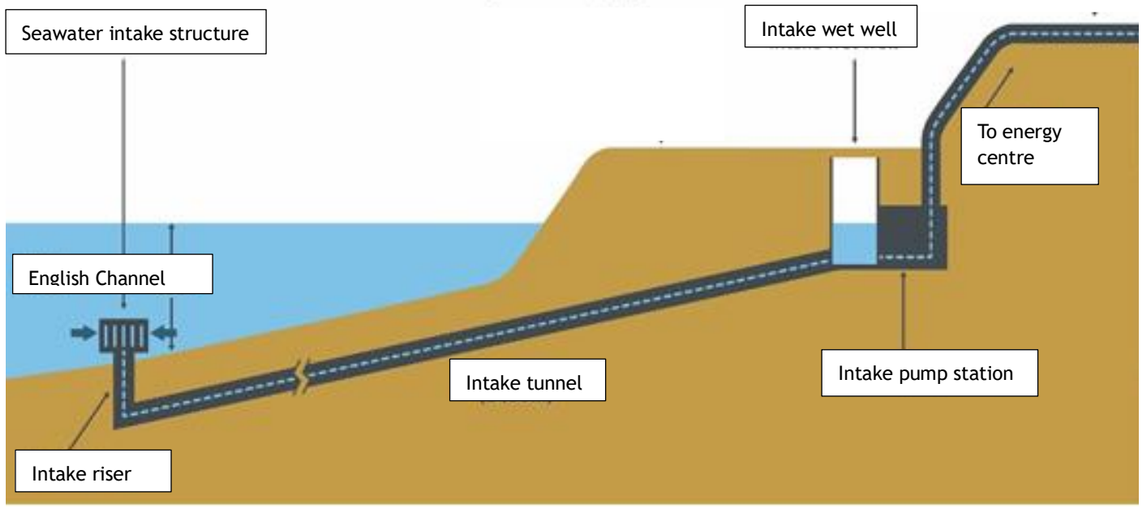


Figure C3-1: Illustration of preferred seawater abstraction system for Worthing

It is unlikely that the volume of sea water that can be extracted would be limited by the EA, there is no upper limit on the potential thermal output of any marine source heat pump, aside from spatial constraints within any energy centre.

C.4 Air Source Heat Pumps

Air Source Heat Pumps (ASHPs) extract energy from the ambient air and are able to function even when temperatures are as low as -5°C.

To extract energy from the ambient air, a portion of the equipment, the collector coil (which functions as either the condenser or compressor depending on if the heat pump is in heating or cooling mode respectively) is located externally. This is typically achieved by placing the coils on roof-spaces (which are flat to enable plant access) or at ground level, as illustrated in Figure F4-1 below:

Figure C4-1: Large capacity ASHP installation examples: Rooftop installation (left) or ground level installation (right, unit shown is 700kW in size and 8m in length, image courtesy of Star Refrigeration).

In order to absorb enough energy from the air, the resultant the collector coil(s) will need to be very large to serve the demands of a centralised district heating system, which typically results in the plant solution taking up a larger footprint than the other viable heat pump solutions discussed in this section.

C.5 Methodology for the Technical System Appraisal

To assess each technology fairly, they are scored against a range of criteria which are of key concern. These criteria fall into four categories:

- **Technical –** Different technologies have been assessed against their suitability to deliver the scale and the profile of the required heat supply and to operate under required supply temperatures. Examples have been called on to provide evidence of technology maturity and the reliability of the technology's integration with a DHN, while security on fuel delivery has been further considered.
- **Environmental -** A range of environmental implications have been considered for each technology. Direct impacts such as pollution and changes to the local air quality have been discussed for the various technologies. The scale of carbon savings has been estimated based on both current and predicted carbon emission factors. The carbon saving for each technology has been discussed in the context of the fuel used, efficiencies attainable and the relevant emission factors.
- **Financial -** The financial benefit of each technology has been assessed in relation to current and projected fuel prices, efficiency and the expected maintenance level required over the technology's lifetime. Long term financial risks were also considered.
- **Deliverability -** Consideration has been given to the criteria that may affect deliverability of the technology, such as reliance on third parties, and implications on space requirement and energy centre size/design. Technologies were further evaluated based on their suitability on a local level.

Each technology was then scored between 1 and 5 against each criterion and shown in a matrix to determine the most viable technology for the DHN. Scores have been attributed on a comparative basis, with a score of 5 awarded to the highest scoring option in any category and reduced scores awarded in relation to the high scoring option.

Using each criterion's weighting importance, the weighted totals were calculated for each technology which allowed the technologies to be ranked. The methodology was conducted for two scenarios; 0-15 years of DHN operation (to reflect the likely first date for plant replacement) and 15+ years of DHN operation.

The table opposite details each criterion and their given 'Importance', a score between one and five, to reflect its impact on the overall assessment. One represents low importance and five represents high importance. Each criterion is then given a proportional weighting, which is calculated based on the score, such that all weightings sum to 100.

C.6 Generation Plant Weighting

Category	Criterion	Relative Importance 1 - 5	Weighting %
Technical	Technology maturity and availability	4	8
	Suitability for scale and profile of heat demand	2	4
	Security of supply	3	6
	Suitability for required supply temperatures	4	8
	Proximity to heat demands	2	4
Environmental	Level of CO_2 emission savings	5	10
	Air quality implications	5	10
	Wider environmental impacts	2	4
Financial	Technology cost	3	6
	Impact on scheme financial viability	5	10
	Long term financial risks	3	6
Deliverability	Planning Implications	5	10
	Implications for energy centre size/design	3	6
	Implications for additional space requirements	2	4
	Reliance on third parties	2	4
			100

C.7 Technology Appraisal Results – District Heating - Current Assessment (0-15 years)

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
Category	Name Ref	Gas Boiler	Gas CHP	Biofuel Boiler	Biofuel CHP	Air Source Heat Pump	Ground Source Heat Pump	Marine Source Heat Pump	Sewer Source Heat Pump	Waste Heat Recovery	Hydrogen Fuel Cell
Technical	Technology maturity and availability	5	5	3	3	5	5	4	3	4	1
	Suitability for scale and profile of heat demand	5	5	4	4	3	3	5	3	3	4
	Security of supply	4	4	1	1	5	4	4	4	4	1
	Suitability for required supply temperatures	5	5	5	5	4	4	4	4	4	5
	Proximity to heat demands	5	5	2	2	5	3	5	4	5	5
Environmental	Level of CO2 emission savings	1	2	2	3	4	5	5	5	5	5
	Air quality implications	2	1	2	1	5	5	5	5	5	5
	Wider environmental impacts	3	3	4	4	5	4	3	5	5	3
Financial	Technology cost	5	3	3	2	4	3	3	2	4	1
	Impact on scheme financial viability	4	5	4	3	3	4	4	4	5	1
	Long term financial risks	3	2	3	2	3	4	3	3	3	1
Deliverability	Planning Implications	1	1	2	2	4	5	5	5	5	5
	Implications for energy centre size/design	5	3	4	3	2	4	2	2	3	3
	Implications for additional space requirements	5	3	3	2	2	5	4	3	5	4
	Reliance on third parties	4	4	2	2	5	3	3	3	3	2
	Total score (%)	**70.00**	**64.40**	**58.00**	**51.60**	**79.20**	**84.80**	**81.20**	**76.80**	**86.40**	**63.20**
	Rank	**6**	**7**	**9**	**10**	**4**	**2**	**3**	**5**	**1**	**8**

C.8 Technology Appraisal Results – District Heating - Future Assessment (15 years +)

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
Category	Name Ref	Gas Boiler	Gas CHP	Biofuel Boiler	Biofuel CHP	Air Source Heat Pump	Ground Source Heat Pump	Marine Source Heat Pump	Sewer Source Heat Pump	Waste Heat Recovery	Hydrogen Fuel Cell
Technical	Technology maturity and availability	5	5	4	4	5	5	5	4	4	4
	Suitability for scale and profile of heat demand	5	5	4	4	3	3	5	4	3	4
	Security of supply	3	3	3	3	5	4	4	4	4	3
	Suitability for required supply temperatures	5	5	5	5	5	5	5	5	5	5
	Proximity to heat demands	5	5	2	2	5	3	5	4	5	5
Environmental	Level of CO2 emission savings	1	2	2	3	3	4	4	4	5	5
	Air quality implications	2	1	2	1	5	5	5	5	5	5
	Wider environmental impacts	3	3	4	4	5	4	3	5	5	3
Financial	Technology cost	5	3	4	2	5	4	4	4	4	3
	Impact on scheme financial viability	5	4	4	3	4	5	5	5	5	3
	Long term financial risks	2	1	3	2	4	5	4	4	4	3
Deliverability	Planning Implications	1	1	2	2	4	5	5	5	5	5
	Implications for energy centre size/design	5	3	4	3	2	4	2	2	3	3
	Implications for additional space requirements	5	3	3	2	2	5	4	3	5	4
	Reliance on third parties	4	4	3	3	5	3	3	3	3	3
	Total score (%)	**69.60**	**60.00**	**64.00**	**56.40**	**83.20**	**88.80**	**86.80**	**84.40**	**89.20**	**80.00**
	Rank	**7**	**9**	**8**	**10**	**5**	**2**	**3**	**4**	**1**	**6**

Appendix D – Key Modelling Assumptions

D.1 Modelling Timing Assumptions

The model assumes that network operation will start upon completion of any development site that includes the EC for that cluster.

D.2 Modelling CAPEX Assumptions

Values are derived from AECOM experience and suitable industry standards (such as SPONS), which have been back checked with contractors during the tender stages of other DH projects to ensure that values are up to date and accurate. In line with a RIBA Stage 2 design, costs are accurate to ±30%.

The key assumptions made in the estimation of the capital costs (CAPEX) of each network option are given below. The model updates the CAPEX values to reflect the user-selected parameters, for example whether a given building is included in the calculations.

D.3 Modelling Asset Replacement Cycle Assumptions

The following assumptions have been made on the required replacement cycles of plant and equipment on the basis that a like-for-like replacement will be sought throughout the network lifespan. All other plant and equipment are assumed to last beyond the project lifetime or is funded by ongoing maintenance costs. Plant replacement at the end of the lifespan is assumed to be accounted for an additional CAPEX cost items when required.

Table D3-1: Replacement cycle assumptions

Technology/asset	Replacement cycle	Source
EC boilers, incl. ancillary equipment	Every 20 years	CIBSE Guide M
Gas CHP	Every 100,000 hours operation	Manufacturers data
Heat pumps	Every 20 years	Manufacturers data
HIUs & internal distribution systems	Every 20 years	Manufacturers data
Heat exchangers	Every 15 years	Manufacturers data
Heat distribution pipework & civils works	Every 50 years	Manufacturers data
Electrical ancillaries & private wire network	Every 40 years	CIBSE Guide M

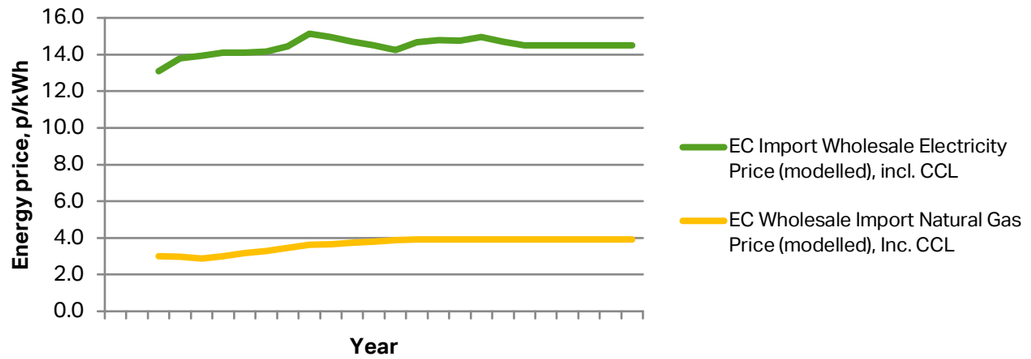
D.4 Modelling OPEX Assumptions

Fuel Costs

Projected fuel unit prices for gas and electricity are based on energy price analysis published by the Department for Business, Energy & Industrial Strategy (BEIS) for industrial customers.

Within the Green Book tables, three bands of prices are given: High, Central and Low for three scales of power consumption: Large scale (Industrial), medium scale (Public Sector/Commercial) and small scale (Domestic). The 'central' price scenario has been used within the model to determine rates of real price inflation from the unit prices paid currently by all the customers on the network.

The figure below shows the HM Treasury Green Book future fuel price projections, showing the Central scenarios for electricity and gas. Whilst the trend of these projections has been used in the model, the projections made in the Green Book do not show any change to price beyond c. 2030, an unlikely scenario.



D.5 Maintenance Costs

Maintenance and staffing costs are assumed to be constant over the lifespan of the project. The figures given in the table below are based on AECOM experience and recent quotes from contractors and developers.

Table D5-1: OPEX assumptions

OPEX item	Metric	Based on	Cost Certainty
EC fabric	1% annually of total Energy centre CAPEX.	Undertaking PPM activities associated with the building. Primary activity will be clearing of gutters and rainwater drainage	Medium Project specific
All generation services.	2.5% p.a of total energy generation services CAPEX.	Value based on SFG20 assessment and based on PPM lead maintenance strategy with limited reactive time. Energy centre to be unstaffed for the majority of the time, other than PPM activities. Value includes allowance for consumables but not reactive replacement of components as this is covered under Sinking Fund	Medium Project specific
Pipework	2.5% p.a of total DHN distribution network CAPEX	Conventional PPM (as per SFG 20)	Medium Project specific
Private Cables	1% p.a of total private wire distribution network CAPEX	Conventional PPM (as per SFG 20)	Medium Project specific
Internal distribution systems	1% p.a of total internal distribution networks CAPEX	Conventional PPM (as per SFG 20)	Medium Project specific

D.6 Modelling Revenue Assumptions

Revenue will come from a number of sources, including direct charges for heat and fixed charges for operation (comparable to standing charges on conventional utility services). For the CHP based options, revenue will also come from any electricity income (from CHP-generated electricity) which may be available through sales to the grid or directly to electricity consumers.

RHI has been excluded from all assessment based on the current forecast end date for the scheme (March 2022) occurring too early for the DEN scheme to realistically meet the required deadlines given the current development stage.

Furthermore, a one-off payment is anticipated to be paid by all the new development sites are anticipated to help cover the cost of connecting each estate to the network. This fee is based upon the cost savings to be made by the developers as a result of the development of a DHN. In each case this corresponds to the cost of installing alternative means of thermal generation and domestic HIUs. In each case, a 25% discount against the BaU costs has been applied to encourage connection considering no planning requirement being in place to necessitate it.

Table D6-1: Revenue assumptions

Development Site	Cluster	Anticipated Connection Charge	Rationale
WICC	A	£62,000	ASHP installation cost
Union Place	A	£510,000	ASHP installation cost
Stagecoach	A	£160,000	ASHP installation cost
British Gas site	A	£320,000	ASHP installation cost
Grafton	A	£490,000	ASHP installation cost
Terville Gate	A	£1,290,000	ASHP installation cost
Worthing Leisure Centre	B	£640,000	ASHP installation cost
HMRC Office site	B	£510,000	ASHP installation cost
Marlett Way	B	£72,000	ASHP installation cost
Centenary House	E		ASHP installation cost

The counterfactual heat price used within the model has been developed for two different BaU scenarios, as detailed in Section 4.

The counterfactual cooling price used within the sensitivity assessment investigating the potential for the addition of a cooling network is based upon the fuel costs only of the existing centralised cooling plant in each applicable site. Costs relating to maintenance and replacement are omitted from this estimation on the basis that any district cooling system would not be a resilient solution and each site would require local backup.

D.7 Modelling Carbon Emission Assumptions

Scheme carbon savings depend on the input fuel and the associated carbon factors of the fuel which is being offset by the heat generation technology. Emissions associated with the combustion of gas are assumed to be constant over the lifetime of the project, where the emission factor used is 0.184kgCO_2e/kWh, based on UK Government GHG Conversion Factors 2018[16]. In cases where grid electricity is displaced by CHP electricity, carbon factors are taken from the BEIS bespoke CHP emissions factors[17] spreadsheet for electricity exported and used on site). This analysis accounts for the decarbonisation of the grid, where emissions are calculated based on the amount of electricity generated by the CHP that is used on site, as opposed to that which is exported. The model calculates the CO_2 emissions savings for each year of operation, based on the forecast carbon factors. Full project life savings will also be reported.

Presently, gas CHP currently delivers carbon savings as the electricity produced is cleaner than that which is taken from the grid. However, as outlined by the DECC emission projections, the CO_2 emissions attributed to grid electricity are expected to fall. As a result, the carbon savings associated with the use of gas CHP schemes is expected to decrease over time. In the case of installations consisting of smaller engines with relatively high heat to power ratios, it is anticipated that they will become net carbon generators (against the BaU case) in the early 2030's.

D.8 Modelling Scheme Ownership Assumptions

The model assumes the network is operated by a separate entity, referred to as the 'ESCo', or Energy Supply Company. Costs are borne by the new company, and if the network includes WBC buildings, then they are treated as any other customer on the network, experiencing the same costs and savings as the other customers.

D.9 Modelling Discount Rates

Discount rates are used to represent the future value of money spent now. In the UK, the government makes decisions based on 'discounted Net Present Value (NPV)', which is a calculation that helps inform whether a capital outlay made today will be worthwhile in the future. The model assumes a constant discount rate over the life of the network of 3.5%[18].

D.10 Financing Options

The model does not consider at this stage the impact of financing (e.g. the cost of raising finance, servicing debt, debt limits, types of credit etc.). The next stage of this study will advance the modelling of a chosen network option, accounting for these elements.

D.11 Tax

VAT is not included in the model as it only has a small impact on the cashflow due to the short construction period. Since this overlaps with operation it is not expected to impact the feasibility of the project.

[16] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526958/ghg-conversion-factors-2016update_MASTER__links_removed__v2.xls

[17] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446512/Emissions_Factors_for_Electricity_Displaced_by_Gas_CHP.xlsx

[18] Based on values taken from https://data.gov.uk/sib_knowledge_box/discount-rates-and-net-present-value,

Appendix E – Full Modelling Results

The suitable EC locations are presented and qualitatively assessed for each cluster, with the highest scoring option chosen for the subsequent analysis. The heat delivery pipework network routes have been derived in order to minimise capital costs by avoiding major environmental constraints whilst ensuring the shortest possible route is taken.

To identify the optimal technical solution for each cluster, multiple different thermal generation scenarios have been be chosen for further analysis utilising the technologies identified as being suitable to the specific area, as identified in Section 3.

E.1 Cluster A: Civic Quarter Expansion / Worthing Town Centre Network

The feasibility assessment, investigating the potential for a DEN within the Worthing Civic Quarter site, identified that either an open-loop ground source or sewer source heat pump led system with backup gas boilers was the preferred solution for the site.

1. The open-loop ground source solution includes of a couplet of boreholes to be installed within the WICC development site, with one abstracting water from the chalk aquifer below the site, and another reinjecting the water back under ground.
2. The sewer source solution includes a connection to the main sewer as it routes alongside the Union Place development site, 200m to the east of the Civic Quarter site.

In both solutions, the generational plant is split across two sites; one being in a new Multi-Story Car Park (MSCP), being developed as part of the Worthing Integrated Care Centre (WICC) site, and the other being within the existing Town Hall basement plant room area.

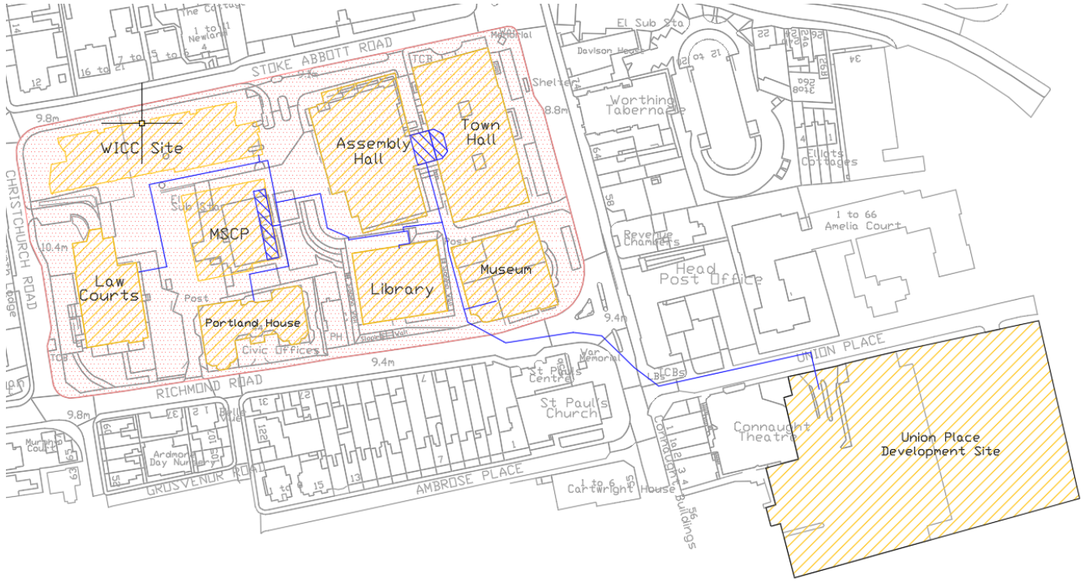


Figure E1-1 Showing the preferred solution for a network serving the Civic Quarter site

The network is required to be operational in time to meet the target heat on date for the WICC site in 2022.

Network Extensions Beyond the Civic Quarter Site

Based on the locations of the identified heating loads within Worthing Town Centre, there is the potential to:

- expand the network to additional sites in the locality of the Civic Quarter;
- branching eastward to Worthing Hospital and Davison and Splashpoint leisure centres; and
- branching southwards towards the retail centre of the town.

Figure E1-2 (overleaf) illustrates these potential extensions.

The economic viability of each of these extensions shall be analysed in isolation in the TEM. Each shall assume that the Civic Quarter network shall be completed in 2022 as per the preferred solution summarised above.

Table E1-1: Building energy demand data for Cluster A

Building	Phase	Heat Consumption, kWh/year	Peak Heat Demand, kW
Town Hall	1	621,648	195
Assembly Hall	1	369,041	240
Portland House	1	181,050	129
Museum & Art Gallery	1	201,700	58
Library	1	153,402	153
Law Courts	1	350,835	321
WICC	1	308,916	97
Union Place - Hotel	1	148,900	53
Union Place - Phase 1 Commercial	1	17,832	6
Union Place - Phase I Residential	1	662,418	701
Guildbourne House	1	236,487	108
Connaught Theatre	1	253,269	126
Stagecoach Site	1	804,226	252
BG Site	1	530,502	512
Teville Gate	1	2,019,443	1,951
Sussex Police West Downs Division	1	55,057	25
Crown Buildings	1	406,530	186
Royal Mail	1	601,965	276
Union Place - Phase 2 Residential	2	93,886	100
Union Place - Phase 2 Comm	2	11,068	3
Davison C of E Secondary School for Girls - WALLACE BUILDING	2	217,928	246
Davison C of E Secondary School for Girls - MAIN BUILDING	2	539,759	610
Worthing Hospital	2	10,767,608	4,020
Splashpoint Leisure Centre	2	2,418,485	758
Worthing Hospital - HOMEFIELD	2	247,958	93
West Sussex Health & Social Care	2	54,938	21
Lyndhurst Infant School	2	99,167	136
Davison Leisure Centre	2	915,062	287
Pavilion Theatre	3	296,402	147
Grafton	3	801,366	774
Cornelia Grange	3	432,588	162
Wicker House	3	133,614	61
41-43 South Street	3	219,635	109
56 Montague Street	3	722,145	358
Debenhams Plc	3	892,955	443
Marks & Spencer Plc	3	1,621,610	804
Beales	3	602,330	299
13-15 South Street	3	261,175	130
Total		**29,272,902**	**14,949 (undiversified) 11,656 (diversified)**

Proposed Network Routes & Phasing Plan

The development of the wider Worthing network has been split into 3 distinct delivery phases, as shown in Figure E1-2 below.

Phase 1 – 2022 Completion

The Civic Quarter site represents the initial core network, delivered in time to meet the heat on date of the WICC site in 2022.

Additional connections can be made from day one to multiple development sites (Terville Gate, Union Place and BG site, with the earliest heat on dates being in 2022) and other existing sites in and around the vicinity of the Civic Quarter.

Phase 2 – 2025 Completion

The network can be extended beyond the core network eastwards to Worthing Hospital, Davison Leisure Centre and Splashpoint Leisure centre.

It is estimated that the commercial agreements, design and construction of these elements could take up to 3 years from the initial heat on date, giving an anticipated completion in 2025.

Phase 3 – 2025 Completion

The network can be extended beyond the core network southwards toward the retail centre and Pavilion Theatre.

It is estimated that the commercial agreements, design and construction of these elements could take up to 3 years from the initial heat on date, giving an anticipated completion in 2025.

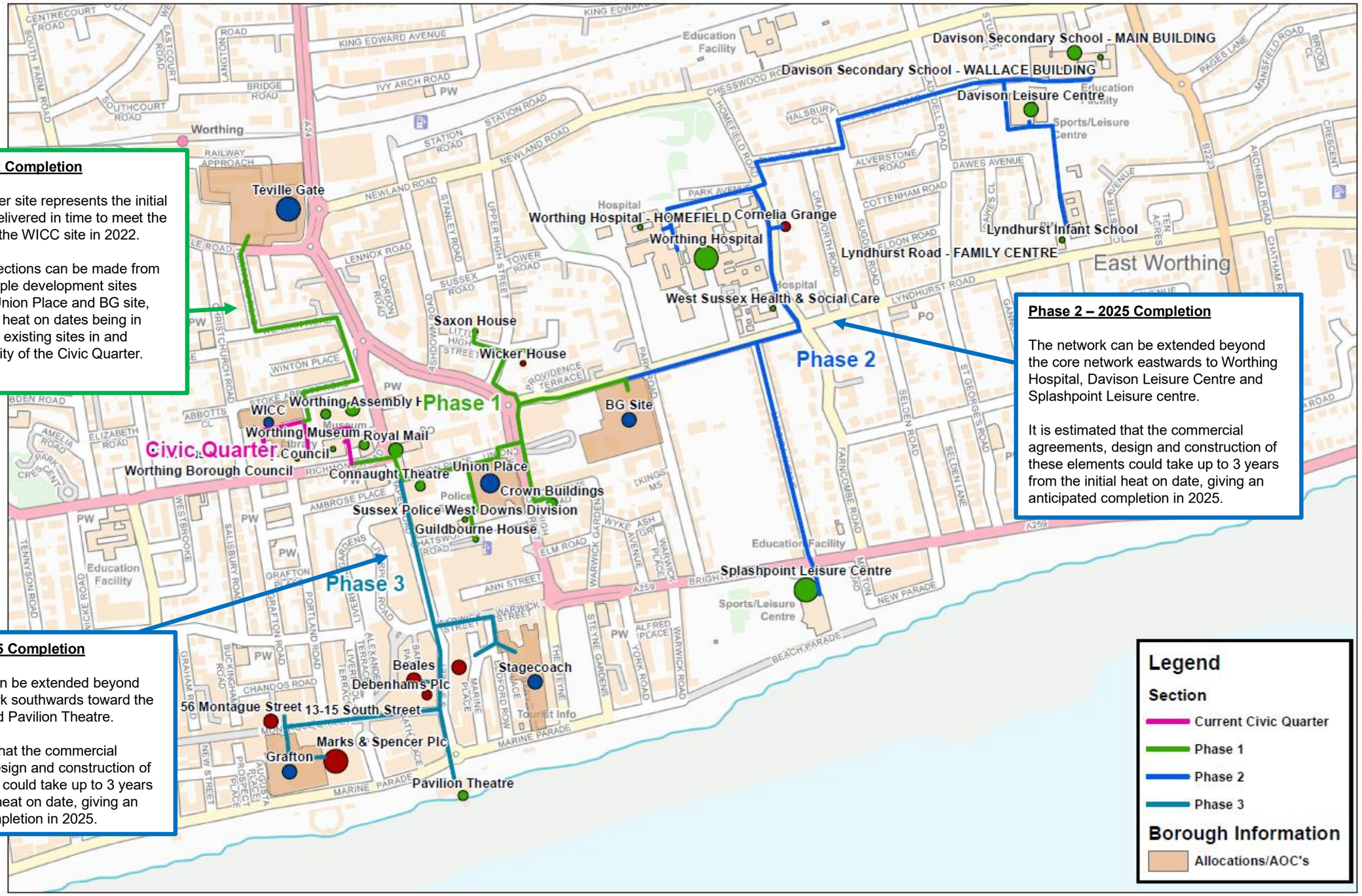


Figure E1-2: Route map showing potential network extension of Civic Quarter network throughout Worthing Town Centre

Additional Ambient Heat Source Locations & Potential EC Locations

Of the two solutions identified to serve the Civic Quarter, only the sewer source system can be expanded to serve the additional heating demands. Should additional capacity be required, additional ambient heat sources can be utilised, as detailed in Figure E1-3 below, with the associated plant located in the identified possible EC locations. Refer to Appendix C for further details of the proposed systems.

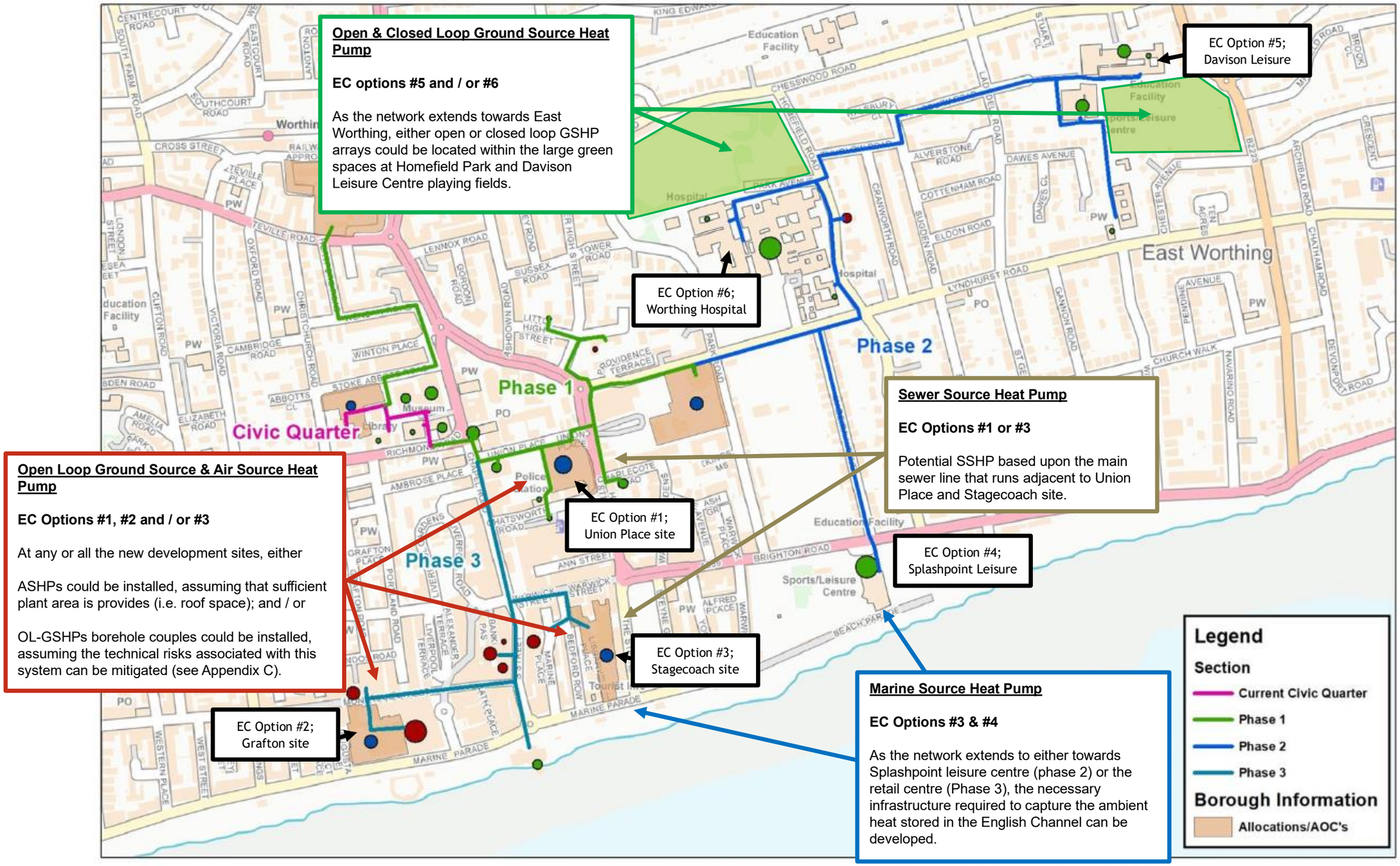

Open & Closed Loop Ground Source Heat Pump
EC options #5 and / or #6
As the network extends towards East Worthing, either open or closed loop GSHP arrays could be located within the large green spaces at Homefield Park and Davison Leisure Centre playing fields.
EC Option #5; Davison Leisure
EC Option #6; Worthing Hospital
Phase 1
Phase 2
Phase 3
Civic Quarter
East Worthing
Sewer Source Heat Pump
EC Options #1 or #3
Potential SSHP based upon the main sewer line that runs adjacent to Union Place and Stagecoach site.
EC Option #1; Union Place site
EC Option #4; Splashpoint Leisure
EC Option #3; Stagecoach site
Open Loop Ground Source & Air Source Heat Pump
EC Options #1, #2 and / or #3
At any or all the new development sites, either
ASHPs could be installed, assuming that sufficient plant area is provides (i.e. roof space); and / or
OL-GSHPs borehole couples could be installed, assuming the technical risks associated with this system can be mitigated (see Appendix C).
EC Option #2; Grafton site
Marine Source Heat Pump
EC Options #3 & #4
As the network extends to either towards Splashpoint leisure centre (phase 2) or the retail centre (Phase 3), the necessary infrastructure required to capture the ambient heat stored in the English Channel can be developed.
Legend
Section
Current Civic Quarter
Phase 1
Phase 2
Phase 3
Borough Information
Allocations/AOC's

Figure E1-3: Energy Recovery Opportunities in Worthing Town Centre

Given the spatial constraints in the two EC locations used, and the limitations of the single couplet OL-GSHP system, there is limited scope to serve additional sites from this system without additional EC locations. The following sites within Worthing Town Centre have been identified as being suitable to locate additional ECs:

ID	Site Location	Site Description	Potential Plant
1	The Union Place development site	Currently empty site which is currently owned by WBC and is allocated as a mixed-use development site that is anticipated to include commercial, retail and residential elements to be delivered between 2022-2025.	SSHP, OL-GSHP, ASHP, gas boilers
2	The Grafton development site	Site that is currently owned by WBC on which there is an operational MSCP. The site is allocated for a mixed-use development, with works anticipated to commence 2024.	MSHP, OL-GSHP, gas boilers
3	The Stagecoach development site	A proposed mixed-use development on the site of the Stagecoach bus depot adjacent to the coast. Proposed residential, leisure and employment use, delivery timeline unknown.	MSHP, OL-GSHP, SSHP, gas boilers
4	Splashpoint leisure centre	A leisure centre site located adjacent to the coast. Operated by South Downs Leisure on behalf of WBC. Opened in 2013.	MSHP, gas boilers
5	Davison leisure centre	A leisure centre site located in East Worthing. Operated by South Downs Leisure on behalf of WBC.	OL-GSHP, CL-GSHP, gas boilers
6	Worthing Hospital	NHS owned and operated hospital, adjacent to Homefield Park	OL-GSHP, CL-GSHP, gas boilers

Table E1-2: Potential additional energy centre locations that could be developed as network expands beyond the Civic Quarter

Network Summary

The features of each network section are described below. The thermal densities of the potential extensions result in a much higher thermal density than the initial core phase, which is representative of the thermal loads being much larger in these areas.

Parameter	Phase 1 – Civic Quarter & local area expansion	Phase 2 – Eastern Extension	Phase 3 – Southern Extension
Number of connections	16	9	8
Largest energy load	Terville Gate development site	Worthing Hospital	Marks & Spencer retail unit
Annual heating demand (MWh)	8.1	13.2	5.4
Peak Load (MW)	4.4	5.0	2.7
Network length (m)	2,269	1,380	670
Heat Density (MWh/m)	3.9	9.5	8.0
Flow & return temperature (°C)		85/55	

Table E1-3: Features of each phase of the proposed Worthing Town Centre network

The feasibility report also identified that the majority of the Civic Quarter sites' internal building temperatures are circa 80°C/70°C flow and return, and recommended lowering them to circa 60°C/30°C. This is because these temperatures better align to maximum output temperatures of the majority of the commercially available heat pumps whilst also ensuring higher operational efficiency.

However, given the technical and commercial complications associated with the lowering of all of the additional heating loads identified for the extended network, it is assumed that the flow and return temperatures of the DEN systems modelled in this study will be suitable to serve the 'traditional' internal heating systems as they currently operate. Therefore, all DENs shall be modelled as operating at 85°C / 55°C flow and return.

Should the initial Civic Quarter network be developed at this lower temperature regime, it is recommended that all proposed additional connections are assessed on a case by case basis as to their suitability to accept lower temperatures – either via the adaptation of internal systems or inclusion of localised thermal top-up plant.

Masterplans Scenarios for Optioneering Analysis

Based on the heat generation opportunities, potential EC locations and proposed phasing strategy, the masterplans detailed in Table E1-3 have been developed for analysis within the TEM. All solutions include gas boiler system as the peaking and resilient technology.

Technology Scenario	Day one LZC	Later phase LZC	EC Location(s)	Summary
DEN #1	OL-GSHP *0.7MW max. capacity*	MSHP	Civic Quarter (phase 1) & either Grafton dev. site or Splashpoint Leisure centre (phase 2).	Feasibility study developed solution #1 (OL-GSHP), with additional MSHP capacity added in Phase 2 to meet additional demands.
DEN #2	OL-GSHP *0.7MW max. capacity*	CL-GSHP	Civic Quarter (phase 1) & either Grafton dev. site or Splashpoint Leisure centre (phase 2).	Feasibility study developed solution #1 (OL-GSHP), with additional CL-GSHP capacity added in Phase 2 to meet additional demands.
DEN #3	SSHP *3MW max. capacity*	Extra SSHP	Civic Quarter & / or Union Place (phase 1 & 2).	Feasibility study developed solution #2 (SSHP), with expanded SSHP capacity added in Phase 2 to meet additional demands.
DEN #4	CL-GSHP *6MW+ max. capacity*	Extra CL-GSHP	Davison Leisure Centre	Alternative scenario where phases 1 and 2 are delivered simultaneously and CL-GSHP serves the whole network.
DEN #5	MSHP *6MW+ max. capacity*	Extra MSHP	Grafton dev. site or Splashpoint Leisure	Alternative scenario where phases 1 and 2 are delivered simultaneously and MSHP serves the whole network.
DEN #6	ASHP *6MW+ max. capacity*	Extra ASHP	Civic Quarter and one other additional EC site	Alternative scenario where ASHP plant serves the whole network.

Table E1-4: Developed energy masterplans for the Worthing Town Centre network

Optioneering Assessment Results

The different projects can be comparatively assessed by considering the resultant Levelised Cost of Energy (LCoH) of each scenario. This figure represents the whole life cycle cost relating to the delivery of energy only, and removes all assumptions associated with recoupling revenue, such as tariff structures and connection fees.

Generation Technology Optioneering

To enable comparative assessment of the different technologies, the DEN scenarios have been modelled with a maximum LZC plant thermal output capacity of 3MW[19], resulting in a ratio of heat delivered by the heat pump plant and gas boiler plant respectively of circa 70% / 30%.

Technology Scenario	Lead Technology	Capital cost, £m	Year 1 LZC plant heat delivered carbon factor, kgC02/kWh	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
BaU #1	Gas boilers (existing sites) ASHPs (new sites)	- £3.1	0.18	6.63	-	-
BaU #2	ASHPs (building level)	£13.4	0.05	12.30	-	-
DEN #1	OL-GSHP & MSHP	£14.1	0.040	9.42	n/a	10.76%
DEN #2	OL-GSHP & CL-GSHP	£12.9	0.039	9.00	n/a	12.48%
DEN #3	SSHP	£11.9	0.036	8.76	n/a	13.15%
DEN #4	CL-GSHP	£12.9	0.039	9.01	n/a	12.47%
DEN #5	MSHP	£14.0	0.040	9.43	n/a	10.88%
DEN #6	ASHP	£10.8	0.048	9.33	n/a	13.26%

Table E1-5: Headline results from DEN generational plant optioneering assessment

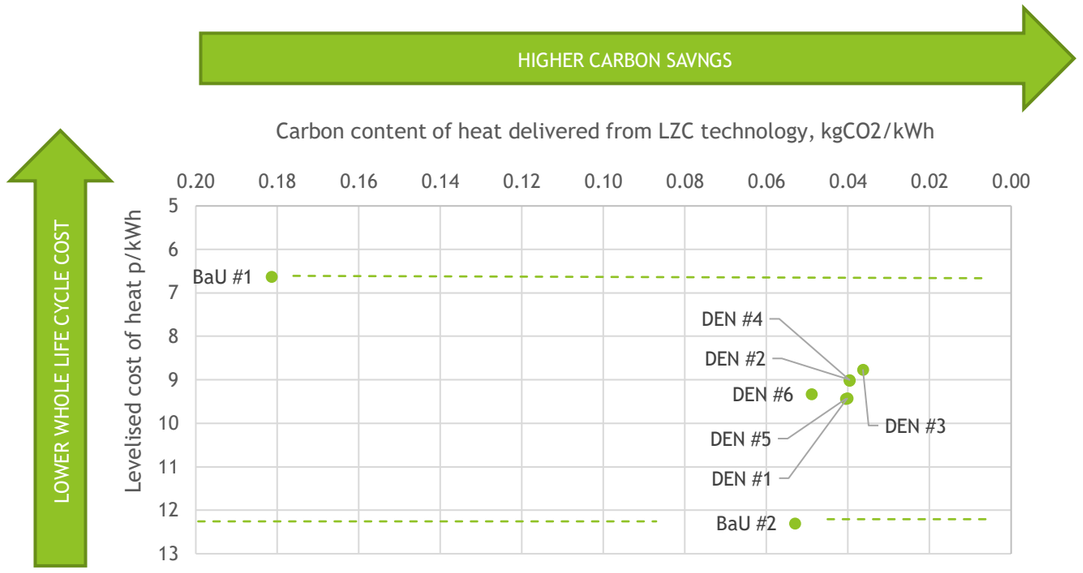


Figure E1-4: The LCoH vs CO_2 savings for the technology optioneering analysis

The generation plant optioneering analysis demonstrates that for a network serving all of Worthing Town Centre:

- All DEN scenarios have higher whole life cycle costs than the continued use of gas boilers in existing sites, therefore customers need to pay more than they currently do (BaU 1) for the project to achieve a positive IRR;
- The lowest whole life cycle cost DEN solution is the SSHP (#3), followed by the CL-GSHP (#4);
- The highest efficiency solution is again the SSHP (#3), followed by the CL-GSHP (#4);
- The lowest capital cost solution is ASHP (#6);
- The capital cost associated with the complex MSHP engineering solution (#5) result in higher whole life cycle costs than all other options; and
- As only 70% of the total town centre heat demand can be delivered by 3MW heat pump solution, a larger system is required to maximise CO_2 saving capabilities in order to meet WBC's carbon commitment requirements.

Based on this analysis, the SSHP option (#3) shall be taken forward as the preferred lead LZC technology. The Civic Quarter feasibility analysis also identified this as one of the preferred solutions as it was shown to be one of the most technically deliverable solutions in the area.

However, as the maximum capacity of the system is estimated at 3MW, a sole SSHP system is insufficient to meet the entire heat demands of the town centre. Therefore, should the network extend to include all the suitable sites identified for connection, additional LZC capacity shall be required. The second highest scoring solution, GSHP, shall be used for this purpose, with the borehole array being installed at Davison Leisure Centre playing fields (if this site is unbailable for this use, an alternative site is Homefield Park).

Distribution Network Coverage Optioneering Results

To assess the viability of the 3 network phases independently of one another, the SSHP and OL-GSHP solution shall be modelled with varying network coverage.

Network Scope Scenario	SSHP Capacity	CL-GSHP Capacity	Capital cost, £m	Levelised cost of Heat, p/kWh (unfunded)	CO_2 reduction versus 'do nothing' BaU (#1)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
Civic Quarter & Union Place	1MW	-	£4.3	11.30	90%	n/a	
Phase 1	1.9MW	-	£7.6	12.33	81%	n/a	5.35%
Phase 1 & 2	3MW	1.6MW	£13.8	10.42	84%	n/a	7.15%
Phase 1 & 3	3MW	-	£9.8	11.04	83%	n/a	7.28%
Whole network	3MW	3MW	£16.3	10.31	85%	n/a	7.79%
BaU #2 – Whole network	*n/a*	*n/a*	*£13.4*	*12.30*	*85%*	-	-

Table E1-6: Headline results from DEN coverage optioneering assessment

The network coverage optioneering results show that a **large scheme serving the whole area should be taken forward for detailed consideration** because:

- The whole life cycle cost of the scheme reduces as the coverage of the network increases in all directions;

[19] This 3MW heat pump plant capacity limit has been selected in accordance with the estimated maximum thermal output of the SSHP plant at Union Place. In the developed option, this ratio shall be increased to circa 99% / 1% in order to better suit WBCs carbon commitments.

- In comparison to the alternative decarbonisation scenario, in which all buildings convert their heating systems from gas boilers to ASHPs individually, a low-carbon heating DEN solution:
    - Has a lower whole life cycle cost, resulting in lower costs to customers despite having a higher capital cost;
    - Results in a comparable CO_2 scheme emission as the replacement of gas boilers with ASHPs in all existing buildings.

The developed scheme presented in the main report (Sections 4 and 5.1) differs from those presented as part of the above optioneering assessment, as it has been optimised to provide the lowest overall cost to the consumers. This has been achieved by:

- Including the maximum level of HNIP grant intervention obtainable in accordance with state aid limits; and
- Reducing the heat tariff rates paid by the consumers in order for the project to achieve a 6% funded IRR.

E.2 Cluster B: Durrington-on-Sea / Worthing Leisure Centre

Summary of network

This network is based around the redevelopment of three sites in close adjacency to one another. The largest is the Worthing Leisure Centre, followed by proposed residential development on the site of the office campus that is currently owned by HMRC.

Detailed redevelopment plans are yet to be developed for either site, therefore the heating loads used within the model have been derived from a series of assumptions (which are detailed in Appendix B).

The core phase of this network is comprised entirely of new developments, which are assumed to have internal heating system temperatures that can utilise lower DH temperatures, i.e. 65°C / 35°C flow and return. It is therefore proposed that the DH system operate with this temperature regime.

The potential network extensions being investigated are entirely comprised of existing buildings, which are assumed to have heating system temperatures of 82°C/71°C flow and return. In the scenarios where the existing buildings are also included, it is therefore proposed that the internal heating systems are adapted in order to be able to make use the lower DHN temperatures. A cost allowance for the required works has been included within the modelling for this purpose.

Energy Centre Locations

The redeveloped Leisure Centre site is the only one within the energy demand cluster that is owned by WBC, therefore it is assumed that it is possible to locate an EC at this location.

Proposed Network Route

The full network is comprised of three sections:

- **A core network** comprised of the energy centre and two new development sites;
- **Extension A**, a pipework extension heading northwards toward 1 the Causeway;
- **Extension B,** a pipework extension heading southwards towards West Park middle school.

The economic viability of each of these elements shall be analysed in isolation in the TEM.

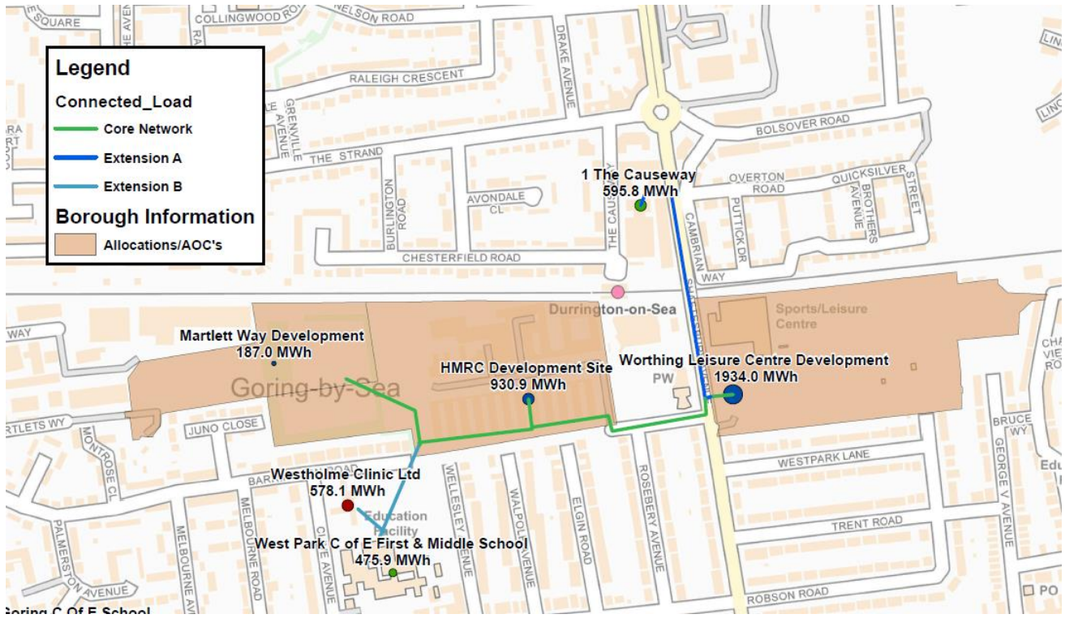


Figure E2-1: Route plan for potential network in Durrington-on-Sea

Table E2-1: Building energy demand data for Cluster B

Building	Phase	Heat Consumption, kWh/year	Peak Heat Demand, kW
Worthing Leisure Centre development	1	1,934,000	606
HMRC development	1	930,920	899
Martlett Way development	1	187,000	86
1 The Causeway	2a	595,757	273
Westholme Clinic	2b	578,082	216
West Park C of E Middle School	2b	578,082	651
Total		**4,701,613**	**2,731 (undiversified) 2,112 (diversified)**

Network Summary

Parameter	Core Network	Extension A	Extension B
Number of connections	3	1	2
Largest energy load	Worthing Leisure Centre	1 The Causeway	Westholme Clinic
Annual heating demand (MWh)	3,051	595	1,053
Peak Load (MW)	1.59	0.27	0.87
Energy centre location	Worthing Leisure Centre		
Network length (m)	642	337	187
Heat density (MWh/m)	4.7	1.8	5.6
Flow & return temperatures (°C)	60/30	85/55	85/55

Table E2-2: Features of each phase of the proposed Durrington-On-Sea network

Masterplans Scenarios

Based on the heat generation opportunities, potential EC locations and proposed phasing strategy, the masterplans detailed in Table E2-2 have been developed for analysis within the TEM. All solutions include gas boiler system as the peaking and resilient technology.

Technology Scenario	LZC	Summary
DEN #1	CL-GSHP *4MW+ capacity*	CL-GSHP led solution, with borehole array installed within Leisure Centre grounds (playing fields).
DEN #2	OL-GSHP *2MW capacity*	OL-GSHP led solution, with multiple borehole couplets installed within Leisure Centre grounds (playing fields).
DEN #3	ASHP *4MW+ capacity*	ASHP led solution, with plant located on Leisure Centre rooftop or in a ground level compound.

Table E2-3: Developed energy masterplans for the Worthing Town Centre network

Results

The different projects can be comparatively assessed by considering the resultant Levelised Cost of Energy (LCoH) of each scenario. This figure represents the whole life cycle cost relating to the delivery of energy only, and removes all assumptions associated with recoupling revenue, such as tariff structures and connection fees.

Generation Technology Optioneering

To enable comparative assessment of the different technologies, the DEN scenarios have been modelled with a maximum LZC plant thermal output capacity of 0.95MW, resulting in a ratio of heat delivered by the heat pump plant and gas boiler plant respectively of circa 98% / 2%.

Technology Scenario	Lead Technology	Capital cost, £m	Year 1 Carbon factor of heat delivered, kgC02/kWh	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
BaU #1	Gas boilers (existing sites) ASHPs (new sites)	- £0.67m	0.18	9.4	-	-
BaU #2	ASHPs (building level)	£2.3m	0.05	12.53	-	-
DEN #1	CL-GSHP	£5.8m	0.03	12.44	n/a	1.63%
DEN #2	OL-GSHP	£5.5m	0.03	11.82	n/a	2.44%
DEN #3	ASHP	£4.8m	0.04	11.82	n/a	2.25%

Table E2-4: Headline results from DEN generational plant optioneering assessment

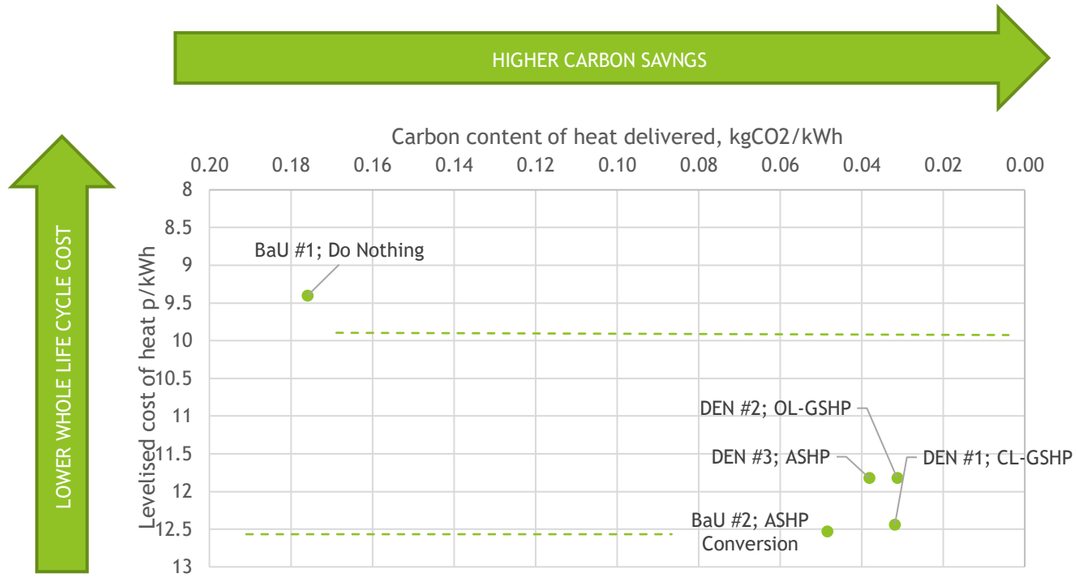


Figure E2-2: The LCoH vs CO_2 savings for the technology optioneering analysis

The generation plant optioneering analysis demonstrates that for a network serving Durrington-on-Sea:

- All DEN scenarios have higher whole life cycle costs than the continued use of gas boilers in existing sites;
- The lowest whole life cycle cost DEN solutions are the OL-GSHP and ASHP;
- The highest efficiency solution is again the OL-GSHP, followed by the CL-GSHP; and
- The lowest capital cost solution is ASHP;

Based on this analysis, the OL-GSHP option shall be taken forward as the preferred lead LZC technology.

In order to be able to deliver the 0.95MW thermal output modelled, it is estimated that between 1 and 3 borehole couplets would be required[20]. To prevent undesirable hydraulic interaction between the boreholes, a minimum spacing of 100m is typically required. Based on this spacing, the playing grounds located the on Worthing Leisure Centre site is are sufficiently large to house the required equipment (refer to Section 5.2 for more details).

[20] This is based upon the condition of the chalk aquifer under the site being comparable to that under the Civic Quarter site, where it is anticipated that a minimum yield of 5 litres / second per borehole should be obtainable, resulting in resultant kWth capacity of 300 – 400 kW per borehole couplet.

Distribution Network Coverage Optioneering Results

To assess the viability of the core phase and 2 proposed network extensions, the OL-GSHP solution shall be modelled with varying network coverage.

ID	OL-GSHP Capacity	Capital cost, £m	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)	CO_2 reduction versus BaU 1
Core network	0.6MW	£4.1m	12.51	n/a	-0.78%	13.0% (BaU all ASHP)
Core & Extension A	0.9MW	£5.1m	12.17	n/a	1.88%	70.5%
Core & Extension B	0.7MW	£4.6m	12.15	n/a	0.27%	60.0%
Whole network	0.95MW	£5.5m	11.82	n/a	2.44%	77.8%
BaU #2 – Whole network	*n/a*	*£2.3m*	*12.53*	-	-	*86%*

Table E2-5: Headline results from DEN coverage optioneering assessment

The network coverage optioneering results show that a **large scheme serving the whole area should be taken forward for detailed consideration** because:

- As the majority of the load on the network is comprised of new developments which have not yet been designed, the mechanical specification of their internal heating systems can be tailored to be able to utilise lower flow and return temperatures, maximising the potential operational efficiency of any DH scheme;
- The whole life cycle cost of the scheme reduces as the coverage of the network increases in all directions;
- In comparison to the alternative decarbonisation scenario, in which all buildings convert their heating systems from gas boilers to ASHPs individually, a low-carbon heating DEN solution:
    - Has a lower whole life cycle cost, resulting in lower costs to customers despite having a higher capital cost;
    - Results in lower CO_2 emissions due to the use of higher efficiency heat pump systems.

The developed scheme presented in the main report (Sections 4 and 5.2) differs from those presented as part of the above optioneering assessment, as it has been optimised to provide the lowest overall cost to the consumers. This has been achieved by:

- Including the maximum level of HNIP grant intervention obtainable in accordance with state aid limits; and
- Reducing the heat tariff rates paid by the consumers in order for the project to achieve a 6% funded IRR.

E.3 Cluster C: Northbrook Campus Cluster

Summary of Network

This network is based around the cluster of commercial energy users with the primary consumers being St Barnabas Hospice, Northbrook College, Haviland House Care Home and a private leisure centre. The core network would connect only the hospice and the college, with subsequent connections being considered as opportunities to extend.

As all sites proposed for inclusion on this network currently exist, the flow and return temperatures modelled correspond to 'traditional' heating system temperatures of 85°C / 55°C flow and return respectively.

Energy Centre Locations

The energy demand site for this network is be the college which would likely have the largest exiting plant capacity (and therefore plantroom space). It has been considered unlikely that either the college or the hospice would have a large enough existing plant room to house an energy centre large enough for the entire network (circa 500m^2 would be required).

The best option would be to utilise existing gas connections and plant space in the college or hospice to house the gas plant which would need to be retained to meet the network peaks in demand and provide resilience. The new low carbon generation would be developed in a new energy centre building located in the carpark for the site for the loss of 10-15 parking spaces.

Proposed Network Route

The full network is comprised of three sections:

- **A core network** comprised of the energy centre and public sites; Northbrook College and St Barnabas hospice;
- **Extension A**, a pipework extension heading eastwards toward Southern House serving private retail units,
- **Extension B,** a pipework extension heading northwards towards David Lloyds Leisure Centre serving private commercial units.

These extensions have been split from the core network to test the impact of private sector loads not connecting. The economic viability of each of these elements shall be analysed in isolation in the TEM.

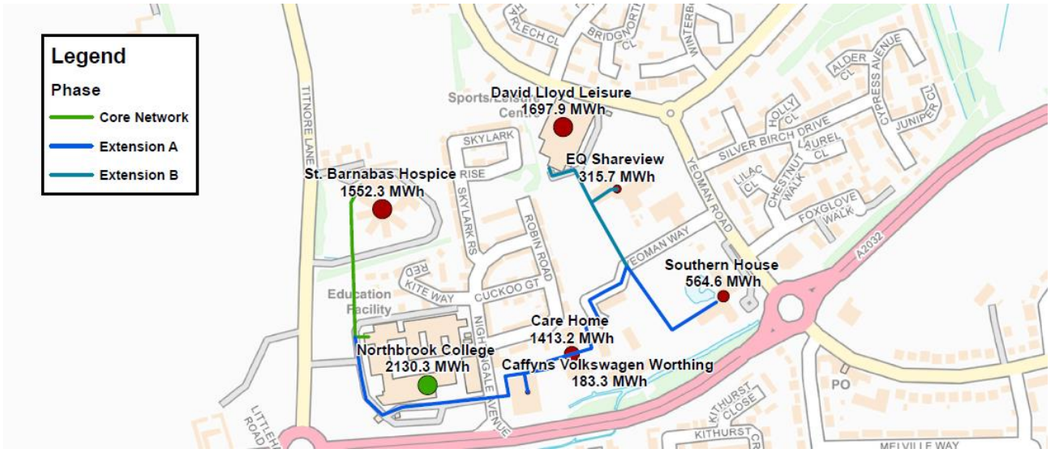


Figure E3-1: Route plan for potential network in Northbrook College Campus

Table E3-1: Building energy demand data for Cluster C

Building	Phase	Heat Consumption, kWh/year	Peak Heat Demand, kW
Northbrook College	Core	2,130,292	2,409
St Barnabas Hospice	Core	1,552,290	580
Caffyns	Ext. A	183,300	91
Haviland Care Home	Ext. A	1,413,168	528
Southern House	Ext. A	564,642	259
EQ Shareview	Ext. B	315,666	145
David Lloyd Leisure	Ext. B	1,697,917	532
Total		**7,857,275**	**4,543 (undiversified) 3,685 (diversified)**

Network Summary

Parameter	Core Network	Extension A	Extension B
Number of connections	2	3	2
Largest energy load	Northbrook College	Haviland Care Home	David Lloyd Leisure
Annual heating demand (MWh)	3,682	2,161	2,013
Peak Load (MW)	2.99	0.88	0.68
Energy centre location	Northbrook College		
Network length (m)	224	796	228
Heat Density (MWh/m)	16.4	2.7	8.8
Flow & return temperature (°C)	85/55	85/55	85/55

Table E3-2: Features of each phase of the proposed Northbrook Campus network

Masterplans Scenarios

Based on the heat generation opportunities, potential EC locations and proposed phasing strategy, the masterplans detailed in Table E3-2 have been developed for analysis within the TEM. Given the large amount of undeveloped arable land in the adjacency of the Northbrook College, there aren't any geographical constraints on the upper limits of GSHP or ASHP generational capacity.

space to install the required borehole arrays or ASHP collectors

All solutions include gas boiler system as the peaking and resilient technology.

Technology Scenario	LZC	Summary
DEN #1	CL-GSHP *4MW+ capacity*	CL-GSHP led solution, with borehole array installed within car park area and / or farm the west of the site
DEN #2	OL-GSHP *4MW+ capacity*	OL-GSHP led solution, with borehole array installed within car park area and / or farm the west of the site
DEN #3	ASHP *4MW+ capacity*	ASHP led solution, with plant located at rooftop or at ground level in a compound within the Northbrook College estate.

Table E3-3: Developed energy masterplans for the Northbrook Campus Network

Results

7.2.1.1 Generation Technology Optioneering Results

To enable comparative assessment of the different technologies, the DEN scenarios have been modelled with a maximum LZC plant thermal output capacity of 1.9MW, resulting in a ratio of heat delivered by the heat pump plant and gas boiler plant respectively of circa 97% / 3%.

Technology Scenario	Lead Technology	Capital cost, £m	Year 1 Carbon factor of heat delivered, kgC02/kWh	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
BaU #1	Gas boilers (existing sites)	-	0.21	5.04	-	-
BaU #2	ASHPs (building level)	£3.8	0.06	13.25	-	-
DEN #1	CL-GSHP	£6.4	0.04	12.29	n/a	5.29%
DEN #2	OL-GSHP	£5.7	0.04	11.54	n/a	6.70%
DEN #3	ASHP	£4.5	0.05	11.91	n/a	6.70%

Table E3-4: Headline results from DEN generational plant optioneering assessment

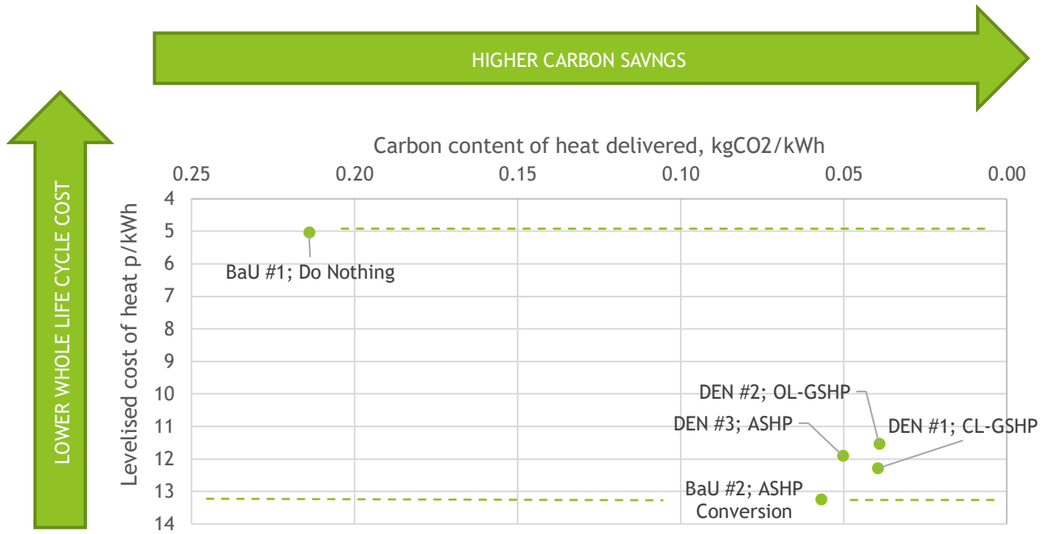


Figure E3-2: The LCoH vs CO_2 savings for the technology optioneering analysis

The generation plant optioneering analysis demonstrates that for a network serving cluster C:

- All DEN scenarios have higher whole life cycle costs than the continued use of gas boilers in existing sites;
- The lowest whole life cycle cost DEN solution is the OL-GSHP, followed by the CL-GSHP with ASHP being the most expensive.
- The highest efficiency solution is again the OL-GSHP, followed by the Cl-GSHP; and
- The lowest capital cost solution is ASHP;

Based on this analysis, the OL-GSHP option shall be taken forward as the preferred lead LZC technology.

In order to be able to deliver the 1.9MW thermal output modelled, it is estimated that between 3 and 5 borehole couplets would be required[21]. To prevent undesirable hydraulic interaction between the boreholes, a minimum spacing of 100m is typically required. Based on this spacing, the arable field located to the West of Northbrook college is sufficiently large to house the required equipment.

[21] This is based upon the condition of the chalk aquifer under the site being comparable to that under the Civic Quarter site, where it is anticipated that a minimum yield of 5 litres / second per borehole should be obtainable, resulting in resultant kWth capacity of 300 – 400 kW per borehole couplet.

7.2.1.2 Distribution Network Coverage Optioneering Results

To assess the viability of the core phase and 2 proposed network extensions, the OL-GSHP solution shall be modelled with varying network coverage.

ID	OL-GSHP Capacity	Capital cost, £m	Levelised cost of Heat, p/kWh	CO_2 reduction versus BaU 1	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
Core network	1.2 MW	£3.7m	13.39	87%	n/a	6.24%
Core & Extension A	1.7 MW	£5.3m	11.70	86%	n/a	6.56%
Core & Extension A & B (whole network)	1.9 MW	£5.7m	11.54	86%	n/a	6.70%
BaU #2 – Whole network	*n/a*	*£3.8*	*13.25*	*86%*	-	-

Table E3-5: Headline results from DEN coverage optioneering assessment

The network coverage optioneering results show that a **large scheme serving the whole area should be taken forward for detailed consideration** because:

- The whole life cycle cost of the scheme reduces as the coverage of the network increases in all directions;
- In comparison to the alternative decarbonisation scenario, in which all buildings convert their heating systems from gas boilers to ASHPs individually, a low-carbon heating DEN solution:
    - Has a lower whole life cycle cost, resulting in lower costs to customers despite having a higher capital cost;
    - Results in a comparable CO_2 scheme emission as the replacement of gas boilers with ASHPs in all existing buildings.

The developed scheme presented in the main report (Sections 4 and 5.3) differs from those presented as part of the above optioneering assessment, as it has been optimised to provide the lowest overall cost to the consumers. This has been achieved by:

- Including the maximum level of HNIP grant intervention obtainable in accordance with state aid limits; and
- Reducing the heat tariff rates paid by the consumers in order for the project to achieve a 6% funded IRR.

E.4 Cluster D: NHS Salvington Hill Estate

Summary of Network

This network is based in the cluster of NHS buildings in Salvington.

All buildings on the network which are assumed to have heating system temperatures of 82°C/71°C flow and return. The network flow and return temperatures modelled (85°C / 55°C) correspond to these 'traditional' heating systems.

Energy Centre Locations

The energy demand site for this network would be the building with the largest exiting plant capacity (and therefore plantroom space). Based on this rationale, the main building has been assumed to be the most suitable. There is also the possibility that a new purpose-built energy centre could be constructed on site for this purpose.

Proposed Network Route

The full network is comprised of a single-phase installation.

Figure E4-1: Route Plan for a potential network around the NHS campus.

Table E4-1: Building energy demand data for Cluster D

Building	Heat Consumption, kWh/year	Peak Heat Demand, kW
Main building	1,275,490	476
Salvington Lodge	622,963	233
Other Offices	461,791	211
Total	**2,360,244**	**920 (undiversified) 882 (diversified)**

Network Summary

Parameter	Network
Annual heating demand (MWh)	2.4MW
Approximate peak load (MW)	0.8MW
Energy centre location	Any suitable building
Network length (m)	350m
Heat density (MWh/m)	7.1 MWh/m
Flow & return temperature (°C)	85/55°C

Table E4-2: Features of each phase of the proposed Centenary House network

Masterplans Scenarios

Based on the heat generation opportunities, potential EC locations and proposed phasing strategy, the masterplans detailed below have been developed for analysis within the TEM.

Given the large size of the campus in addition to the adjacent arable land to the west, there aren't any geographical constraints on the upper limits of GSHP or ASHP generational capacity.

All solutions include gas boiler system as the peaking and resilient technology.

Technology Scenario	LZC	Summary
DEN #1	CL-GSHP *4MW+ capacity*	CL-GSHP led solution, with borehole array installed within Durrington High School playing fields.
DEN #2	OL-GSHP *4MW+ capacity*	OL-GSHP led solution, with borehole array installed within Durrington High School playing fields.
DEN #3	ASHP *4MW+ capacity*	ASHP led solution, with plant located at rooftop or at ground level in a compound within the Centenary House site.

Table E4-3: Developed energy masterplans for cluster D

Results

Generation Technology Optioneering Results

To enable comparative assessment of the different technologies, the DEN scenarios have been modelled with a maximum LZC plant thermal output capacity of 0.5MW, resulting in a ratio of heat delivered by the heat pump plant and gas boiler plant respectively of circa 99% / 1%.

Technology Scenario	Lead Technology	Capital cost, £m	Year 1 Carbon factor of heat delivered, kgCO2/kWh	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
BaU #1	Gas boilers (existing sites)	-	0.21	5.05	-	
BaU #2	ASHPs (building level)	£0.8m	0.06	11.57	-	
DEN #1	CL-GSHP	£1.9m	0.04	11.79	n/a	3.21%
DEN #2	OL-GSHP	£1.7m	0.04	11.16	n/a	4.33%
DEN #3	ASHP	£1.6m	0.05	12.04	n/a	2.37%

Table E4-4: Headline results from DEN generational plant optioneering assessment

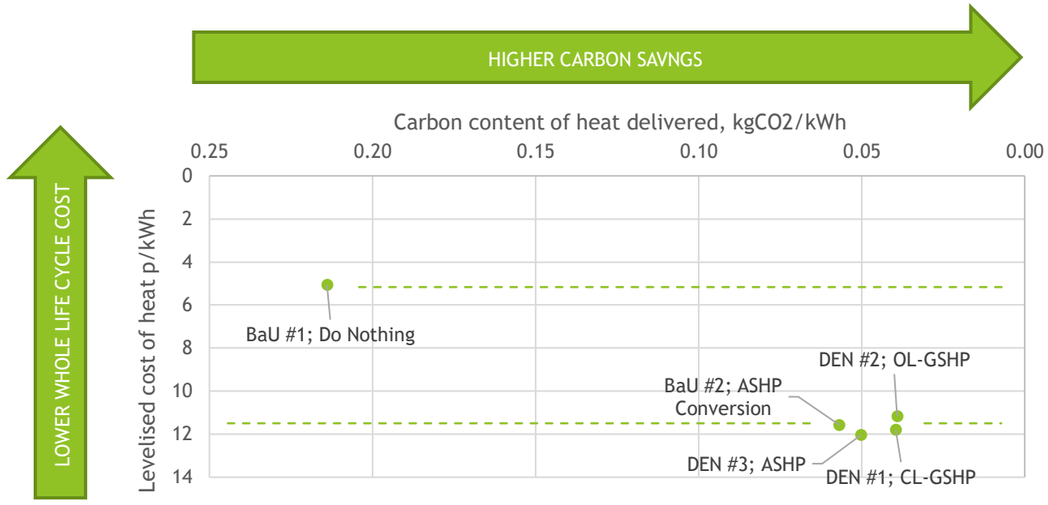


Figure E4-2: The LCoH vs CO_2 savings for the technology optioneering analysis

The generation plant optioneering analysis demonstrates that for a network serving cluster D:

- All DEN scenarios have higher whole life cycle costs than the continued use of gas boilers in existing sites;
- Only the OL-GSHP solution has a lower whole life cycle cost than the installation of building level ASHPs
- The lowest whole life cycle cost DEN solution is the OL-GSHP, followed by the ASHP with CL-GSHP being the most expensive.
- The highest efficiency solution is again the OL-GSHP, followed by the Cl-GSHP; and
- The lowest capital cost solution is ASHP;

The plant optioneering results show that a **scheme serving the whole area should be taken forward for detailed consideration** because:

- In comparison to the alternative decarbonisation scenario, in which all buildings convert their heating systems from gas boilers to ASHPs individually, a low-carbon heating DEN solution:
  - Has a lower whole life cycle cost, resulting in lower costs to customers despite having a higher capital cost;
  - Results in a comparable CO_2 scheme emission as the replacement of gas boilers with ASHPs in all existing buildings.

Based on this analysis, the OL-GSHP option shall be taken forward as the preferred lead LZC technology.

In order to be able to deliver the 0.5 MW thermal output modelled, it is estimated that between 1 and 2 borehole couplets would be required[22]. To prevent undesirable hydraulic interaction between the boreholes, a minimum spacing of 100m is typically required. Based on this spacing, the NHS campus is sufficiently large to house the required equipment.

The developed scheme presented in the main report (Sections 4 and 5.4) differs from those presented as part of the above optioneering assessment, as it has been optimised to provide the lowest overall cost to the consumers. This has been achieved by:

- Including the maximum level of funding support (either through HNIP or RHI) obtainable in accordance with state aid limits; and
- Reducing the heat tariff rates paid by the consumers in order for the project to achieve a 6% funded IRR.

[22] This is based upon the condition of the chalk aquifer under the site being comparable to that under the Civic Quarter site, where it is anticipated that a minimum yield of 5 litres / second per borehole should be obtainable, resulting in resultant kWth capacity of 300 – 400 kW per borehole couplet.

E.5 Cluster E: Centenary House /Durrington High School

Summary of Network

This network is based around a connection between the proposed Centenary House redevelopment and Durrington High School. Between these two anchor loads, several other buildings could also connect to the network, the majority of them being educational facilities.

While the Centenary House development may be able adopt a lower temperature regime, it is anticipated that for all other buildings on the network a higher temperature network would be preferable. The flow and return temperatures modelled correspond to 'traditional' heating system temperatures of 85°C / 55°C flow and return respectively.

Energy Centre Locations

The latest information on the Centenary House Development is that the site is due to be demolished and reconstructed. This provides a good opportunity to integrate a low carbon energy centre into their designs. While it would be preferable to have a single energy centre there may be an opportunity for all gas plant to be located in the Durrington High School site, potentially avoiding the need for the new development to require a gas connection.

Proposed Network Route

The full network is comprised of two sections:

- **A core network** comprised of the energy centre, Centenary House and the Primary Schools;
- **Extension A**, a pipework extension heading westwards to Palatine Primary School.

This extension has been split from the core network due to the lower thermal density of the route. The economic viability of each of these elements shall be analysed in isolation in the TEM.

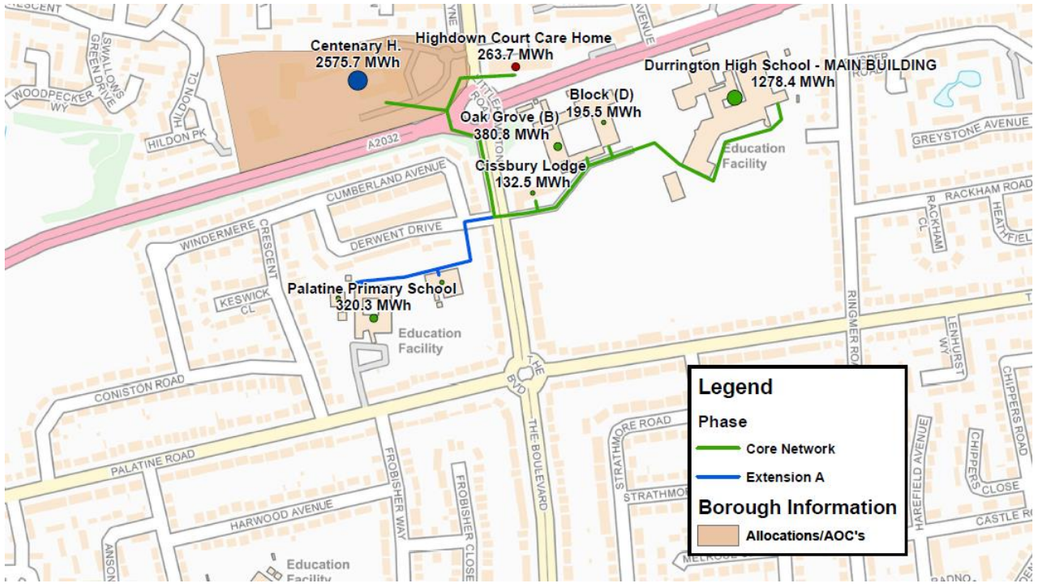


Figure E5-1: Route Plan for a potential network from Centenary House.

Table E4-1: Building energy demand data for Cluster E

Building	Phase	Heat Consumption, kWh/year	Peak Heat Demand, kW
Centenary House Development	Core	2,575,670	807
Cissbury Lodge	Core	132,488	49
Oak Grove College Block D	Core	195,547	221
Oak Grove College Block B	Core	380,796	431
Durrington High School	Core	1,278,396	1446
Highdown Court Care Home	Core	263,700	98
Palantine Primary	Extension	365,293	500
English Martyrs Primary	Extension	137,558	188
Total		**5,329,450**	**3,741 (undiversified) 3,202 (diversified)**

Network Summary

Parameter	Coe Network	Extension A
Number of connections	6	2
Largest energy load	Centenary House	Palatine Primary School
Annual heating demand (MWh)	4,563	503
Approximate peak load (MW)	2.95	0.68
Energy centre location	Centenary House	
Network length (m)	916	267
Heat density (MWh/m)	4.9	1.8
Flow & return temperature (°C)	85/55	85/55

Table E5-1: Features of each phase of the proposed Centenary House network

Masterplans Scenarios

Based on the heat generation opportunities, potential EC locations and proposed phasing strategy, the masterplans detailed in Table E5-2 have been developed for analysis within the TEM. Given the size of both the Centenary House development site and Durrington High School playing field, there aren't any geographical constraints on the upper limits of GSHP or ASHP generational capacity.

All solutions include gas boiler system as the peaking and resilient technology.

Technology Scenario	LZC	Summary
DEN #1	CL-GSHP *4MW+ capacity*	CL-GSHP led solution, with borehole array installed within Durrington High School playing fields.
DEN #2	OL-GSHP *4MW+ capacity*	OL-GSHP led solution, with borehole array installed within Durrington High School playing fields.
DEN #3	ASHP *4MW+ capacity*	ASHP led solution, with plant located at rooftop or at ground level in a compound within the Centenary House site.

Table E5-2: Developed energy masterplans for cluster E

Results

Generation Technology Optioneering Results

To enable comparative assessment of the different technologies, the DEN scenarios have been modelled with a maximum LZC plant thermal output capacity of 1.7MW, resulting in a ratio of heat delivered by the heat pump plant and gas boiler plant respectively of circa 99% / 1%.

Technology Scenario	Lead Technology	Capital cost, £m	Year 1 Carbon factor of heat delivered, kgCO2/kWh	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
BaU #1	Gas boilers (existing sites) ASHP (Centenary House)	- £0.68m	0.21	7.32	-	-
BaU #2	ASHPs (building level)	£3.14m	0.06	13.43	-	-
DEN #1	CL-GSHP	£5.5m	0.04	13.37	n/a	3.87%
DEN #2	OL-GSHP	£5m	0.04	12.46	n/a	5.34%
DEN #3	ASHP	£3.8m	0.05	12.52	n/a	5.77%

Table E5-3: Headline results from DEN generational plant optioneering assessment

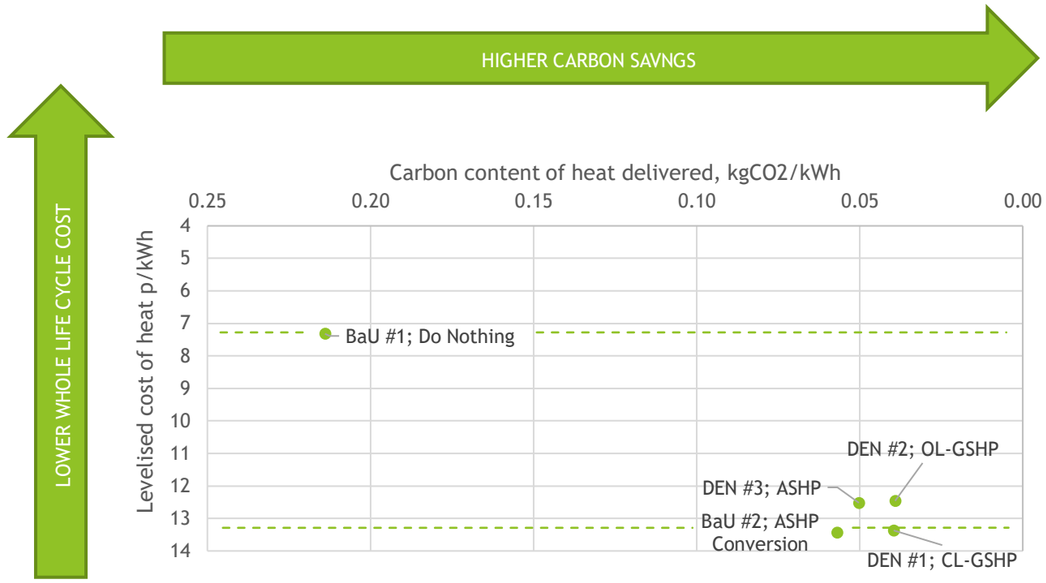


Figure E5-2: The LCoH vs CO_2 savings for the technology optioneering analysis

The generation plant optioneering analysis demonstrates that for a network serving cluster D:

- All DEN scenarios have higher whole life cycle costs than the continued use of gas boilers in existing sites;
- The lowest whole life cycle cost DEN solution is the OL-GSHP, followed by the CL-GSHP with ASHP being the most expensive.
- The highest efficiency solution is again the OL-GSHP, followed by the Cl-GSHP; and
- The lowest capital cost solution is ASHP;

Based on this analysis, the OL-GSHP option shall be taken forward as the preferred lead LZC technology.

In order to be able to deliver the 1.7MW thermal output modelled, it is estimated that between 3 and 5 borehole couplets would be required[23]. To prevent undesirable hydraulic interaction between the boreholes, a minimum spacing of 100m is typically required. Based on this spacing, the arable field located to the West of Northbrook college is sufficiently large to house the required equipment.

[23] This is based upon the condition of the chalk aquifer under the site being comparable to that under the Civic Quarter site, where it is anticipated that a minimum yield of 5 litres / second per borehole should be obtainable, resulting in resultant kWth capacity of 300 – 400 kW per borehole couplet.

7.2.1.3 Distribution Network Coverage Optioneering Results

To assess the viability of the core phase and 2 proposed network extensions, the OL-GSHP solution shall be modelled with varying network coverage.

ID	OL-GSHP Capacity	Capital cost, £m	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)	CO_2 reduction versus BaU 1
Core network	1.2 MW	£4.2m	11.83	n/a	5.31%	77%
Core & Extension	1.7 MW	£5m	12.46	n/a	5.34%	79%
BaU #2 – Whole network	*n/a*	*125%*	*13.43*	-	-	*77%*

Table E5-4: Headline results from DEN coverage optioneering assessment

The network coverage optioneering results show that a **large scheme serving the whole area should be taken forward for detailed consideration** because:

- Although the whole life cycle cost of the scheme increases (+5%) with the inclusion of the Palatine and English Martyrs schools, the resultant whole life cycle cost remains smaller than the BaU #2 and the overall carbon savings from the scheme are increased;
- In comparison to the alternative decarbonisation scenario, in which all buildings convert their heating systems from gas boilers to ASHPs individually, a low-carbon heating DEN solution:
    - Has a lower whole life cycle cost, resulting in lower costs to customers despite having a higher capital cost;
    - Results in a comparable CO_2 scheme emission as the replacement of gas boilers with ASHPs in all existing buildings.

The developed scheme presented in the main report (Sections 4 and 5.5) differs from those presented as part of the above optioneering assessment, as it has been optimised to provide the lowest overall cost to the consumers. This has been achieved by:

- Including the maximum level of HNIP grant intervention obtainable in accordance with state aid limits; and
- Reducing the heat tariff rates paid by the consumers in order for the project to achieve a 6% funded IRR.

E.6 Cluster F: Northbrook Central Campus

Summary of Network

The smallest of the assessed networks connects the heating systems of the Northbrook Metropolitan College Site and Bohunt school, both of which were opened in 2015.

Considering that both sites are of modern construction, it is anticipated that only simple adaptations to their current heating systems would be required to lower their operational temperatures to those better suited to heat pump operation. For this purpose, a high-level capital allowance of £100,000 for each of the college and school has been included within the cost plan and the network has been modelled to operate at 65/35°C flow and return temperatures.

Energy Centre Locations

Given the constrained nature of the site a new energy centre should be avoided. There would need to be investigation into the available plant room space available in either the Main College Building or the Bohunt School teaching block. Alternatively, there are several outbuildings which could be converted into energy should there not be a suitable space in the main buildings.

It has been assumed for the purpose of this study that there is an available plant room space in the main college building.

Proposed Network Route

The network aims to connect all the main buildings on the site. Due to the small size of the network, any economic results will be sensitive to the location of connection points to the network and number of plantrooms (within a single building) which need to be connected.

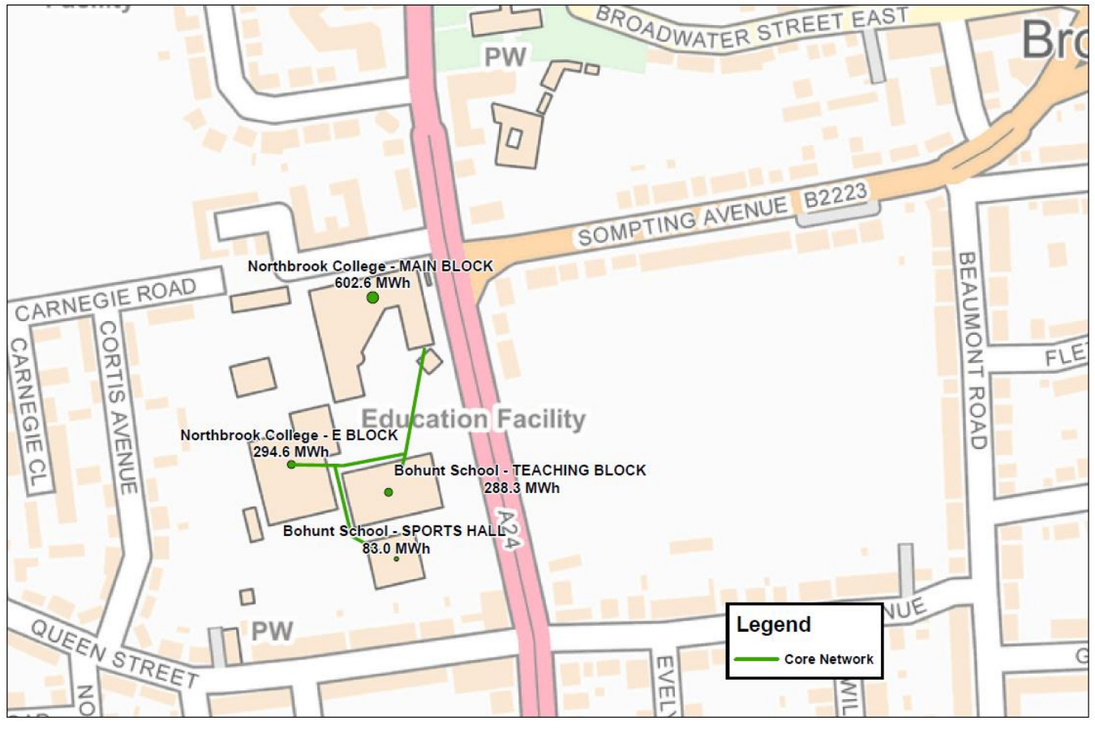


Figure E6-1: :Route plan for a small network connecting the Bohunt School and Northbrook College Sites.

Building	Heat Consumption, kWh/year	Peak Heat Demand, kW
College Main Building	602,000	681
College Block E	615,000	696
Bohunt School Teaching Block	288,000	326
Bohunt School Sports Hall	83,000	26
Total	**1,588,000**	**1,728 (undiversified) 1,728 (diversified)**

Table E5-1: Building energy demand data for Cluster F

Parameter	Core Network
Number of connections	4
Largest energy load	Northbrook College Main building
Annual heating demand (MWh)	1,588
Peak Load (MW)	1.43
Energy centre location	Northbrook College Main building
Network length (m)	190
Heat Density (MWh/m)	8.3
Flow & return temperature (°C)	65/35

Table E6-1: Features of each phase of the proposed Northbrook Central network

Masterplans Scenarios

Based on the heat generation opportunities and potential EC locations, the masterplans detailed in Table E6-2 have been developed for analysis within the TEM. As the site is adjacent to the large Manor Sports Ground playing fields site, there aren't any geographical constraints on the upper limits of GSHP generational capacity. Both the college and the school also have large flat-roof areas that could be used to house ASHP plant for use in a DEN.

All solutions include gas boiler system as the peaking and resilient technology.

Technology Scenario	LZC	Summary
DEN #1	CL-GSHP *4MW+ capacity*	CL-GSHP led solution, with borehole array installed within Manor Sports Ground playing field
DEN #2	OL-GSHP *4MW+ capacity*	OL-GSHP led solution, with borehole array installed within Manor Sports Ground playing field
DEN #3	ASHP *4MW+ capacity*	ASHP led solution, with plant located at rooftop of the main buildings at either Northbrook College building or Bohunt school.

Table E6-2: Developed energy masterplans for cluster F

Results

Generation Technology Optioneering Results

To enable comparative assessment of the different technologies, the DEN scenarios have been modelled with a maximum LZC plant thermal output capacity of 0.7 MW, resulting in a ratio of heat delivered by the heat pump plant and gas boiler plant respectively of circa 99% / 1%.

Technology Scenario	Lead Technology	Capital cost, £m	Year 1 Carbon factor of heat delivered, kgCO2/kWh	Levelised cost of Heat, p/kWh (unfunded)	Project IRR; BaU 1 heat tariff scenario (unfunded)	Project IRR; BaU 2 heat tariff scenario (unfunded)
BaU #1	Gas boilers (existing sites)	-	0.21	5.86	-	-
BaU #2	ASHPs (building level)	£1.5m	0.04	15.89	-	-
DEN #1	CL-GSHP	£2.4m	0.03	15.84	n/a	3.72%
DEN #2	OL-GSHP	£2.2m	0.03	14.61	n/a	4.88%
DEN #3	ASHP	£2m	0.04	14.71	n/a	4.82%

Table E6-3: Headline results from DEN generational plant optioneering assessment

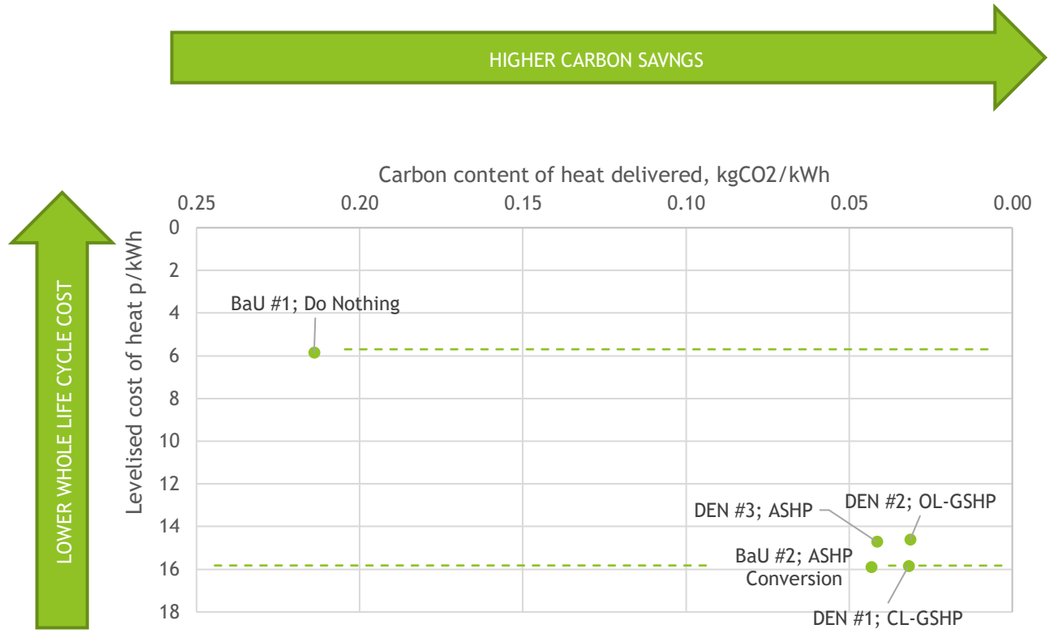


Figure E6-2: The LCoH vs CO_2 savings for the technology optioneering analysis

The generation plant optioneering analysis demonstrates that for a network serving cluster F:

- There is insufficient heat demand on the network to be eligible for HNIP grant funding (which required a network delivering a minimum of 2MWh per annum), therefore the levelised costs are relatively higher than the other clusters analysed in more detail;
- All DEN scenarios have higher whole life cycle costs than the continued use of gas boilers in existing sites;
- The lowest whole life cycle cost DEN solution is the OL-GSHP, followed by the ASHP with CL-GSHP being the most expensive.
- The highest efficiency solution is again the OL-GSHP, followed by the Cl-GSHP; and
- The lowest capital cost solution is ASHP;

The plant optioneering results show that a **scheme serving the whole area should be taken forward for detailed consideration** because:

- In comparison to the alternative decarbonisation scenario, in which all buildings convert their heating systems from gas boilers to ASHPs individually, a low-carbon heating DEN solution:
    - Has a lower whole life cycle cost, resulting in lower costs to customers despite having a higher capital cost;
    - Results in a comparable CO_2 scheme emission as the replacement of gas boilers with ASHPs in all existing buildings.

Based on this analysis, the OL-GSHP option shall be taken forward as the preferred lead LZC technology.

In order to be able to deliver the 0.7 MW thermal output modelled, it is estimated that between 2 and 3 borehole couplets would be required[24]. To prevent undesirable hydraulic interaction between the boreholes, a minimum

[24] This is based upon the condition of the chalk aquifer under the site being comparable to that under the Civic Quarter site, where it is anticipated that a minimum yield of 5 litres / second per borehole should be obtainable, resulting in resultant kWth capacity of 300 – 400 kW per borehole couplet.

spacing of 100m is typically required. Based on this spacing, the Manor Sports Playing Ground is sufficiently large to house the required equipment.

The developed scheme presented in the main report (Sections 4 and 5.6) differs from those presented as part of the above optioneering assessment, as it has been optimised to provide the lowest overall cost to the consumers. This has been achieved by:

- Including the maximum level of funding support (either through HNIP or RHI) obtainable in accordance with state aid limits; and
- Reducing the heat tariff rates paid by the consumers in order for the project to achieve a 6% funded IRR.

aecom.com